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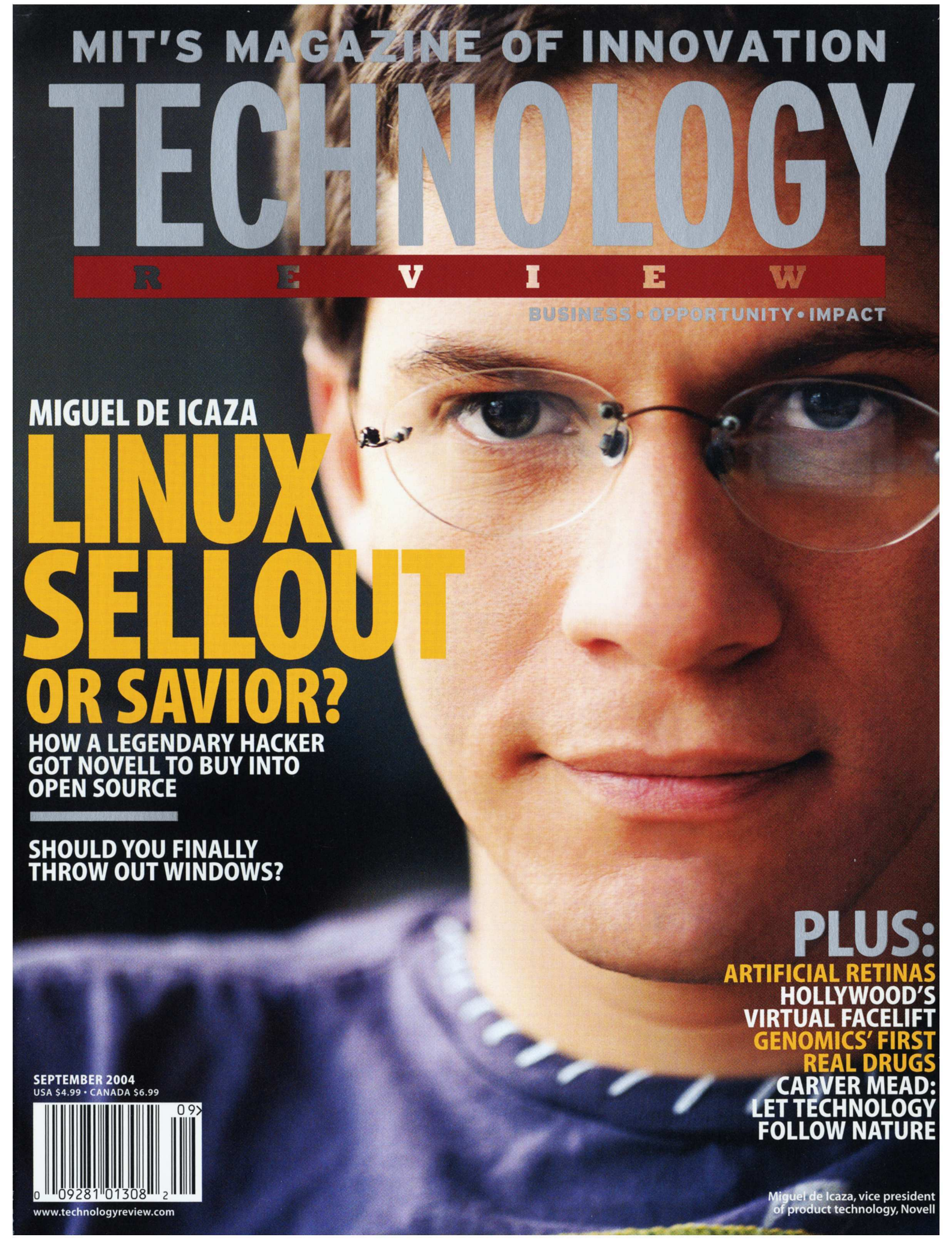

MIGUEL DE ICAZA

LINUX SELLOUT OR SAVIOR?

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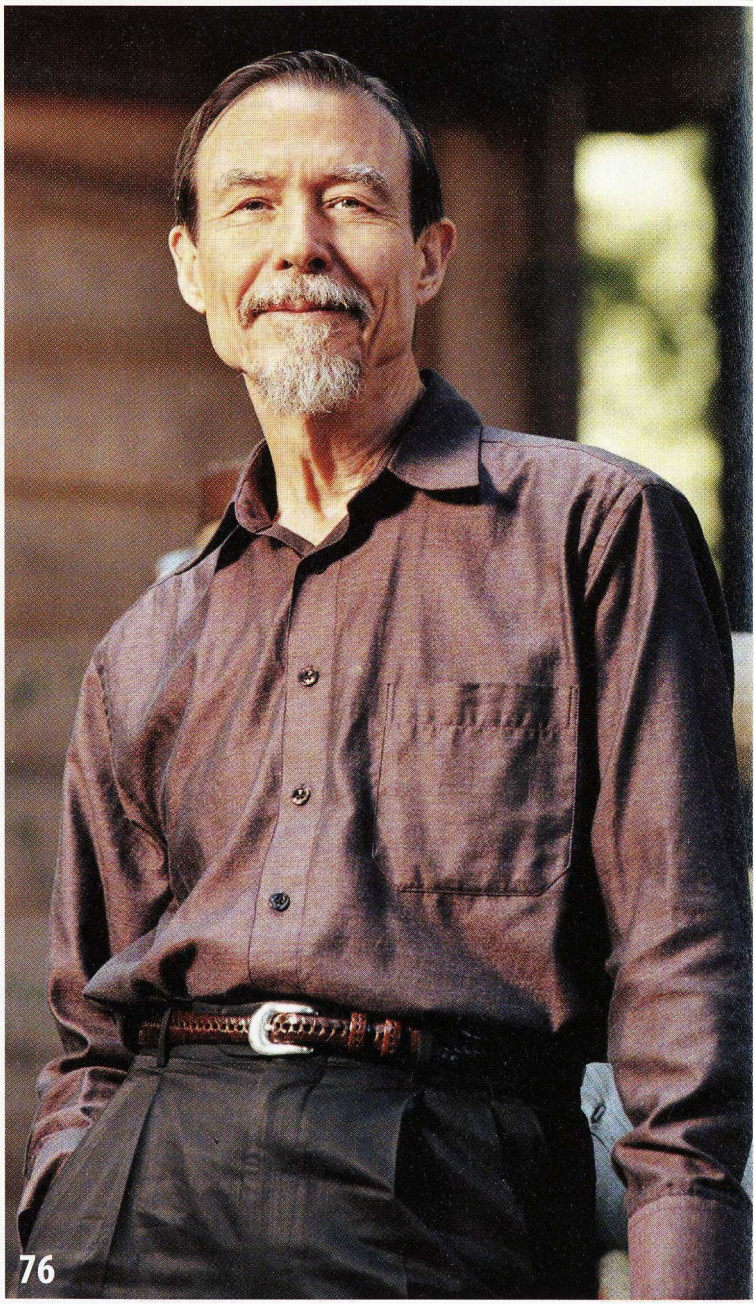
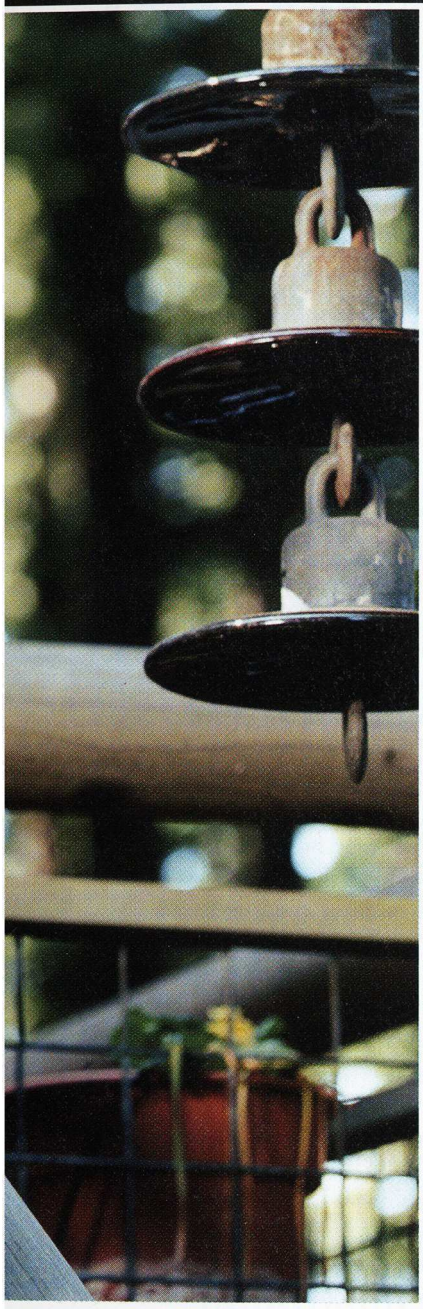


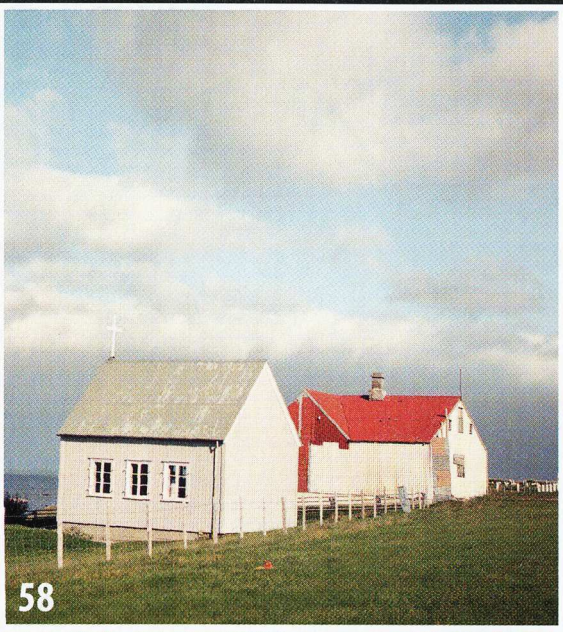
FEATURES

DEPARTMENTS

Technology Review
Volume 107, Number 7
September 2004

"Open source is the ticket out of the banality Microsoft has imposed." —*Louis Suárez-Potts, p. 55*





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IN EVERY ISSUE

COLUMNS

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Getting the Whole Story

ONE OF THE GREATEST SATISFACTIONS FOR A TECHNOLOGY JOURnalist is getting the chance to see how a story actually plays out. Watching how a new technology evolves after the exciting early days when its potential seems unlimited often provides valuable insights into the innovation process. ■ So earlier this summer, *TR* associate editor Corie Lok got out her compass and atlas to track down the progress of one of biotech's hottest stories of the late 1990s—how Iceland's deCode Genetics planned to mine the genomes and health records of that tiny nation. The company's ambitious founders saw a unique opportunity to combine the explosion in genomic information with the detailed genealogic records that traced an isolated population across generations. The promise was breakthroughs in understanding the genetics of various diseases, better and safer drugs, and the start of a whole new era of personalized medicine, in which drugs are tailored to a patient's genetic profile.

The beginnings of deCode, however, were mired in controversy, most of it centered on worries over privacy and a general unease about granting a single biotech company ownership over a population's genetic legacy *(see "Your Genetic Destiny for Sale," TR April 2001)*. The good news, as Lok reports, starting on page 58, is that almost everyone she met in Iceland, from cab drivers to patients, now embraces the effort. What's more, the experiment seems to be working: deCode reports its pipeline is bursting with potential drugs—including a promising one for treating heart disease—gleaned from its gene-hunting efforts.

Revisiting this story yields a few clear lessons. First, a country's public attitude to technology does matter. Second, and just as important, given the right climate, public views can evolve. Efforts comparable to deCode's in the United States and the United Kingdom met similar fears and were either quickly shut down or, as in the case of the U.K. Biobank, slow to get off the ground. (The U.K. Biobank now says it will get fully under way in September 2005.) To their credit, the people of Iceland dealt with the issues, compromised, and efficiently pushed ahead with what many now recognize as vitally important medical research. Perhaps it was a courage in the face of the unknown inherited from Viking ancestors.

It is hard to read Lok's well-reported article and not think of the fate of another hot biotech story that also began to unfold in the late 1990s: stem cell research. Embryonic stem cells, which are able to form any type of body tissue, offer fresh hope for treating everything from Alzheimer's to spinal-cord injuries, but the controversy surrounding them has seriously hampered research. Granted, the ethical issues that initially swirled around deCode and those still raging around stem cell research are vastly different, but one senses that opponents of both share much of the same vague and generalized distrust of the science. Only, unlike deCode's gene hunting, stem cell research is a story that, to a large extent, has not been allowed to play out. In the United States, at least, politics have overwhelmed any fruitful ethical debates and any possible compromise.

But as the people of Iceland have taught us, there are often practical and sensible ways to move beyond such political blind alleys to mine the medical benefits of today's most exciting biotech advances. **David Rotman**

NEXT ISSUE

TR100

In this issue we will announce our annual selection of the world's top innovators under age 35. In the five years since we began this tradition, inclusion among the TR100 has become one of the most prestigious awards for young innovators around the world. In addition to introducing this year's honorees, this special issue will highlight and explain the innovations that they are pioneering in computing, biotechnology, and nanotechnology. The selection process for the TR100 involves an extensive yearlong search for the best and the brightest. Once nominated, the hundreds of candidates are rigorously judged by some of the world's most prominent technologists. The result is an elite group of people whose visions and inventions will shape the future of technology.

Tim Berners-Lee

TR interviews Tim Berners-Lee, inventor of the World Wide Web, about the state of his invention—the threats it faces, the concerns it raises, and the future that awaits it. Get an inside view of the progress on the "Semantic Web," a network of specially formatted snippets of data that automatically add context and meaning to digital information—and promise to take the Web to a new level of usefulness.

The Future of Storage

IBM researchers pioneered many of the key advances in magnetic data storage, the technology behind floppy disks, hard drives, and 40-gigabyte iPods. Last year, however, IBM sold its magnetic-storage business, including its ongoing research, to Hitachi. We'll tell you how IBM came to see greater possibilities in other storage technologies—and why Hitachi thinks magnetic storage is still ripe for improvements.

And more...

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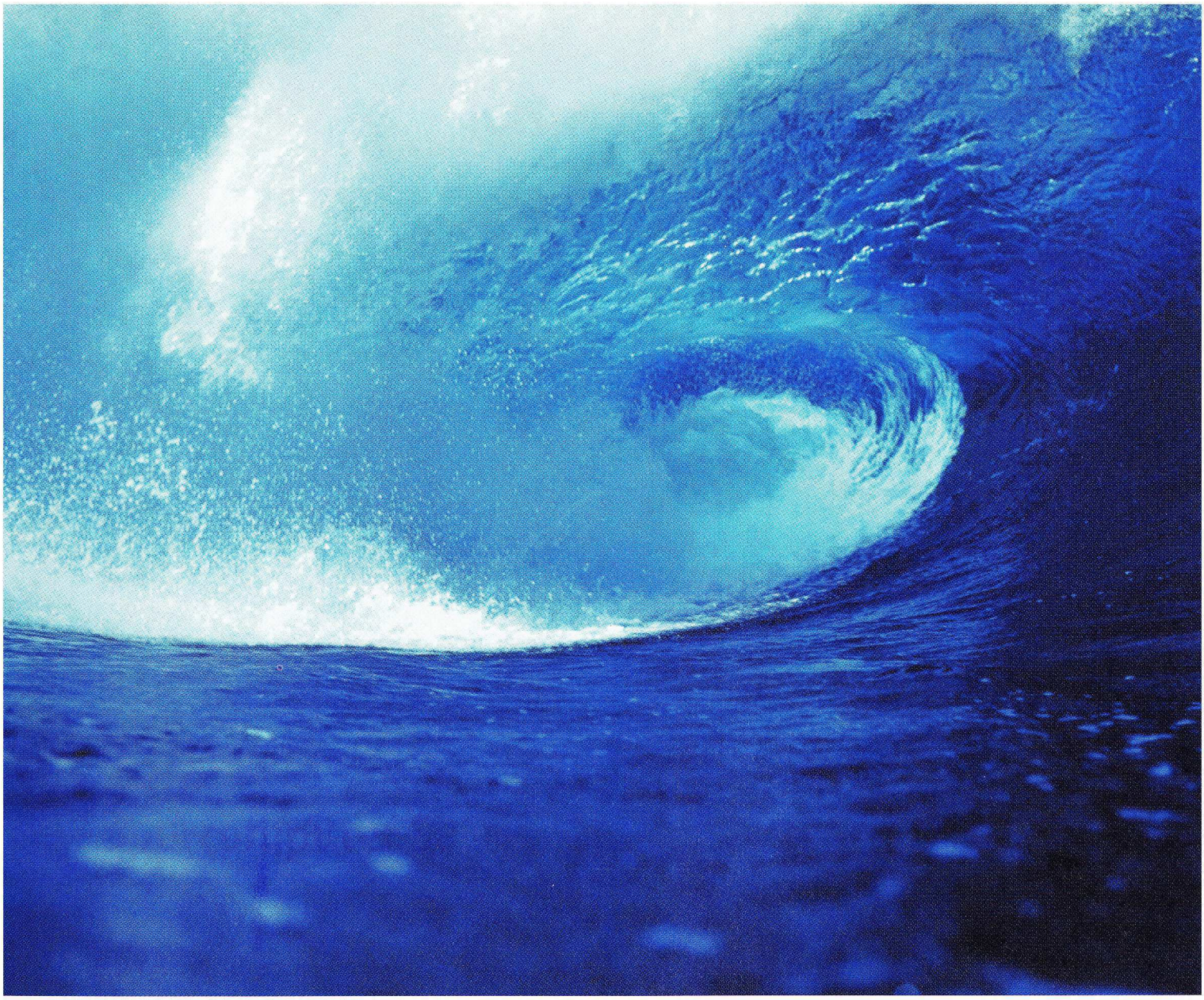

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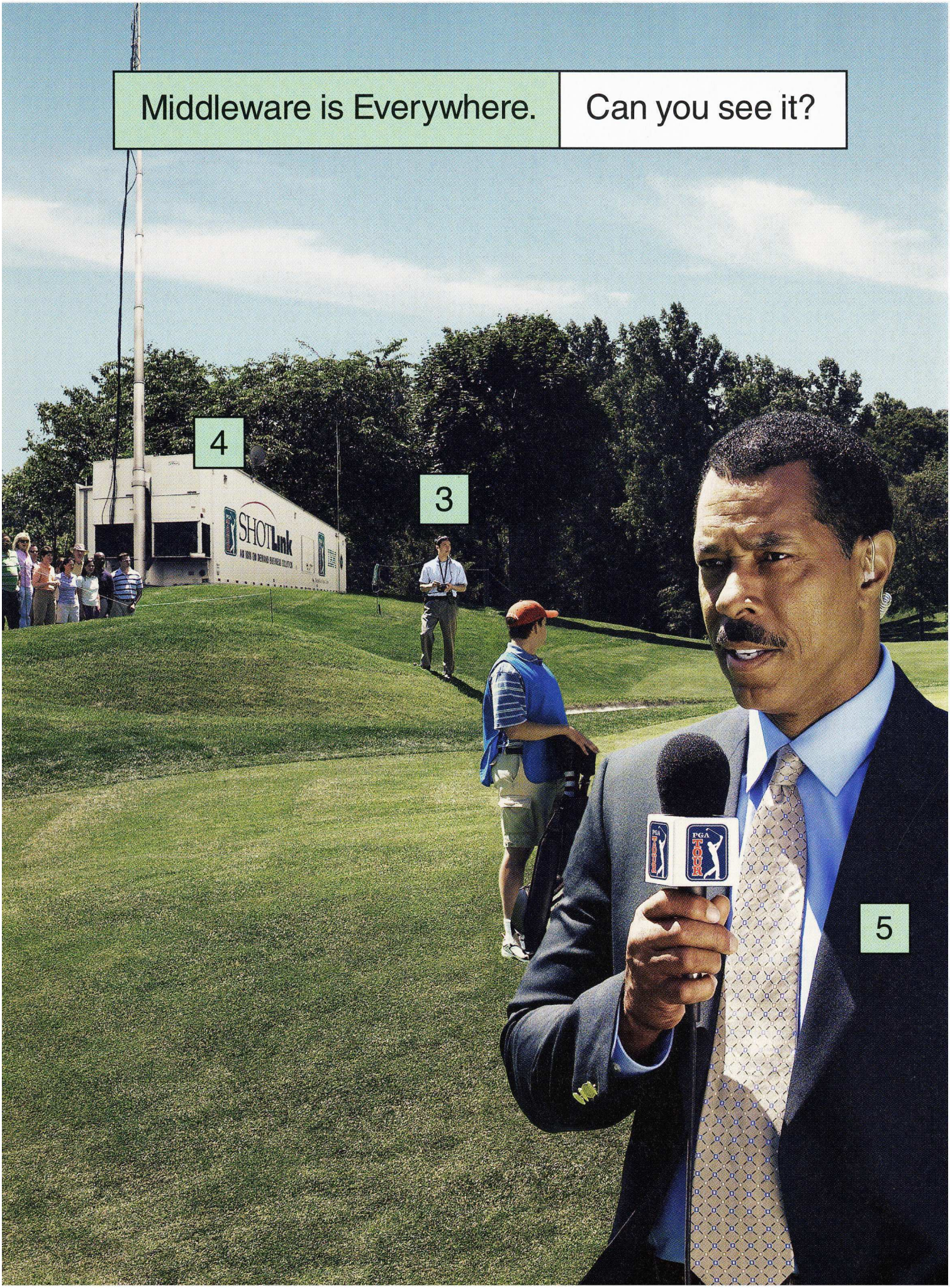
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IBM

"I have learned...that IT is a catalyst of excellence but also an accelerator of incompetence."

OPTIMISTIC OUTSOURCING

THE EDITORIAL ENTITLED "INSOURCING" (*TR* June 2004) indicates that fostering strong ties between the foreign organization and U.S. headquarters causes everyone to be more motivated, more productive, and due to the abundance of new products, happier. Not so fast. Even if we accept that this strategy will promote the development of new products, the most significant employment outcomes will depend on where and how those products are created, serviced, and supported. Those decisions will depend on where those operations will be most profitable. It is by no means obvious to me that development of a new software product in a Chinese lab will mean more tech support jobs in the United States. If anything, successful overseas product development will encourage parent companies to outsource production and post-production work as well.

Richard Cartwright
Essex Junction, VT

I.T. MATTERS

ROBERT METCALFE MISSED THE POINT of Nicholas Carr's article "IT Doesn't Matter" ("Why IT Matters," *TR* June 2004). As any technology becomes ubiquitous, it loses competitive advantage. Take, for example, the phone system or e-mail. These technologies are only ever noticed when they are not working. No one would ever claim that competitive advantage results from using the latest version of Microsoft Exchange. The ubiquity factor neutralizes any added efficiencies. Organizations should demand a justifiable return on any investment, not just IT. To argue that today a company could become the next Dell simply by duplicating Dell's IT is silly. Without a new killer app or a new technical advancement, IT is simply an expense to be reduced and managed.

Brian Courtney
North Andover, MA

AS METCALFE ARGUES, INFORMATION technology does indeed matter when applied competently. Despite considerable initial skepticism, almost everyone these days gives IT much of the credit for the astonishing increase in the nation's productivity over the past few years. Almost every organization is obliged to keep current in IT lest it fall dangerously behind its competitors. A more interesting question is whether an organization can gain a differential advantage through IT. The evidence is that it can, but only if it is able to develop an information system that effectively supports management objectives and that can adapt to changing needs. Success calls for an uncommon blend of technical and managerial competence. Many of us have been victims, as managers and consumers, of mindless and intractable business processes, inflexible systems, unfriendly human interfaces, and bewildering management reports. That these problems are so common shows that getting information technology right is by no means easy. The few organizations that do it extremely well—Dell and Wal-Mart come to mind—demonstrate just how powerful IT can be.

James C. Emery
Carmel, CA

I TAKE ISSUE WITH ROBERT METCALFE'S assertion that I have made "a second career of studies not finding benefits" of information technology. I am passionate about the vast importance of IT as a competitive advantage commercially as well as militarily. My 1955 master's thesis, completed at MIT, is now considered to be the first business-application study of IT ever produced. All I have learned since leaving MIT is that IT is a catalyst of excellence but also an accelerator of incompetence.

Paul A. Strassmann
New Canaan, CT

AN EYE ON THE HERD

HERE IN THE UNITED KINGDOM, WITH farming methods and procedures much more antiquated than in the United States, we have had reasonable success tracking animals ("Where's the Beef From?" *TR* June 2004). Small to large farms have come up to speed with tagging animals and reporting on their whereabouts throughout the chain. DNA samples at slaughterhouses, ear tags, and now, more frequently, RFID tagging of the animals have brought forward many other benefits to the farmers, such as electronic food allocation to animals based on identity and automatic animal sorting by age, type, and weight. The main problem is cost and the perception that the government is incapable of administering the system and resolving problems. Foot and mouth, mad-cow disease, and other maladies have been sobering here, and most in the industry have come to accept that greater accountability and traceability is good for both business and consumers' well-being.

D. Butler
Maughold, Isle of Man

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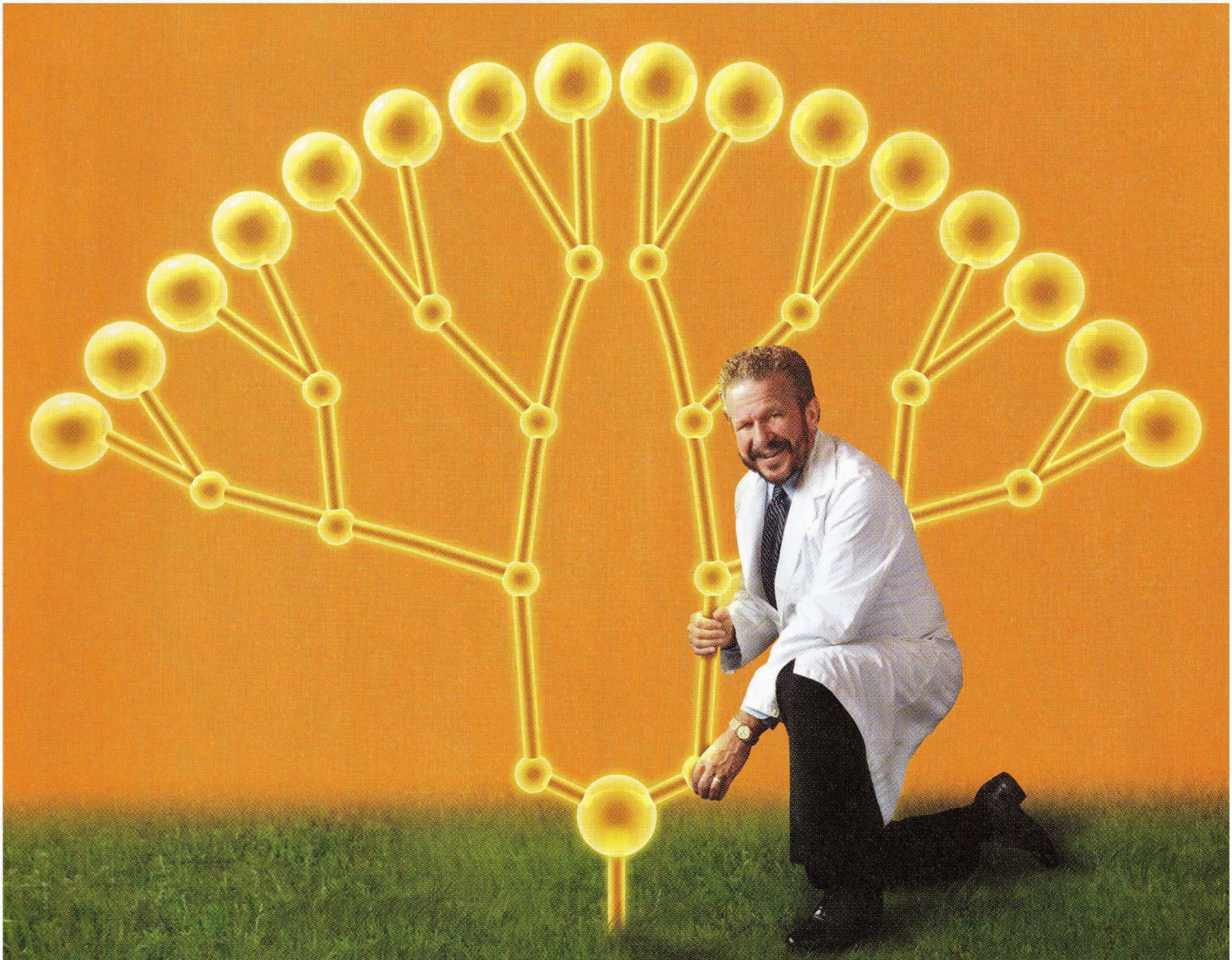

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BRACE YOURSELF

A NEW KNEE BRACE THAT USES "SMART FLUIDS" to provide resistance could change post-injury rehabilitation for millions of people, making repetitive exercises simpler and the needed equipment lighter. Northeastern University mechanical engineer Constantinos Mavroidis and his collaborators have used electro-rheological fluids—materials whose viscosity changes in response to an electric field—to develop actuators that can provide controllable resistance with the flip of a switch. Grafting the actuators onto a standard knee brace converts it into a piece of exercise equipment, which could potentially replace bulky weight machines. And by using a computer to regulate the voltage applied to the actuators, the researchers can vary the brace's resistance over time, making it smarter than traditional gym machines. Mavroidis would eventually like to license the technology for use in exercise equipment, but for now he's concentrating on orthotics. An elbow brace should be finished by fall's end, and Mavroidis has talked with Spaulding Rehabilitation Hospital in Boston, MA, about tests of the knee brace that could begin as early as this fall.

"Smart fluids" control this brace.

ELFIN AERIAL

A team at the University of Florida led by electrical engineer Kenneth O has built a tiny antenna that can send a radio signal across a room. Only three millimeters long and 100 micrometers wide, the antenna is the first of its size with so great a range—about five meters. The tiny antenna is an important step toward O's goal of building an entire radio transceiver on a single microchip. The most likely applications for such radios, he says, are in cheap, robust sensor networks for security systems or for monitoring the safety of bridges or buildings; the radios would send data wirelessly from the sensors to a central monitoring computer. And one company has approached O about using the radios to make interactive toys. He hopes to have built prototypes of complete on-chip radios in about two years; in the meantime, his team is working to improve the antennas' range to at least 20 meters.

PHONE IT IN

PUBLIC TOUCH-SCREEN DISPLAYS SUCH AS AIRPORT CHECK-IN KIOSKS AREN'T known for having versatile interfaces; they usually lack keyboards or pointing devices, limiting users to a few navigational buttons. But new software from High Energy Magic of Cambridge, England, turns a camera phone with a Bluetooth wireless connection into a portable mouse and keyboard that can take full command of public displays, doing away with the old touch screen. Working with Intel's Cambridge research lab, High Energy Magic has developed a set of circular symbols, similar in concept to bar codes, that can be displayed by public terminals. Camera phones loaded with the company's software can translate the symbols into data. Once a phone locks onto one of the symbols, it uses the Bluetooth short-range wireless protocol to send information about its size, position, and orientation to the computer running the display. The phone can then act as a mouse, manipulating on-screen controls such as scroll bars. The company plans to license the technology to businesses, such as travel agencies, that operate public kiosks.

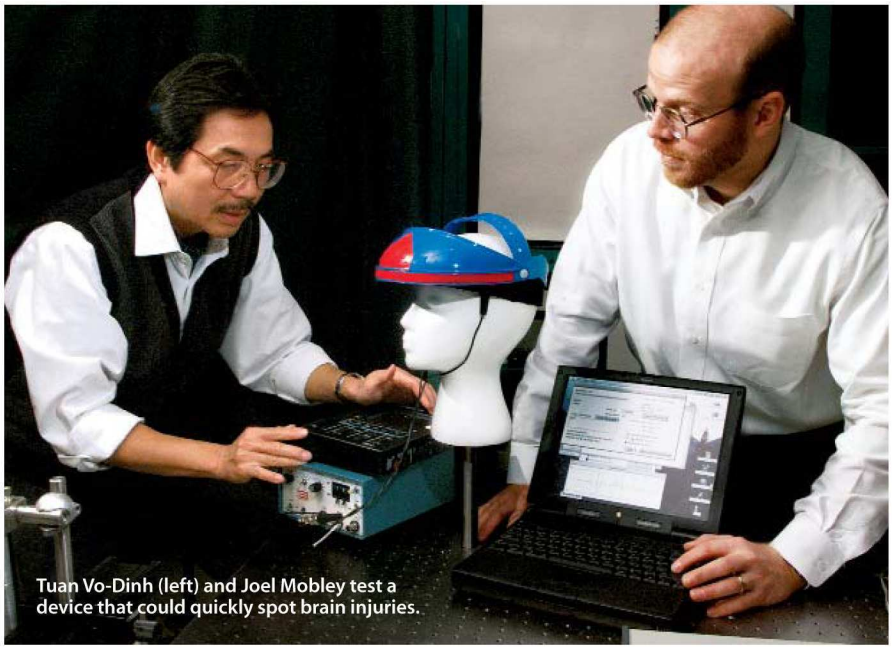
Circular symbols turn a camera phone into a wireless mouse.

STENT AND DELIVER

DRUG-COATED STENTS—WIRE-MESH TUBES used to prop open clogged arteries—are a boon for heart disease sufferers. But in time, the body uses up the drug coating, which prevents scar tissue from blocking the artery again. Researchers at Drexel University in Philadelphia, PA, have developed a replenishable stent. Zachary Forbes, a biomedical engineering doctoral student, plated stents with a weak magnetic alloy. He and fellow grad student Benjamin Yellen then embedded the scar-preventing drugs in biodegradable magnetic nanospheres. To administer the drugs, doctors would inject the nanospheres and switch on an external magnetic field, causing the stent to capture the nanospheres. The scheme would let doctors readminister drugs throughout a patient's (hopefully long) life, adjusting dosages or changing medication. Forbes and Yellen have formed Magnetic BioSystems to commercialize the invention.

Nanoparticles carry drugs to the mesh fibers of a stent.

COURTESY OF HIGH ENERGY MAGIC (PHONE); ZACH FORBES (STENT); JASON NIKITCZUK (BRACE)



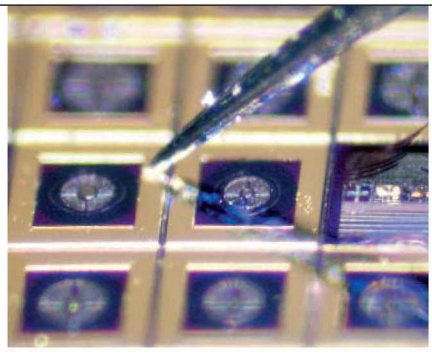
Tuan Vo-Dinh (left) and Joel Mobley test a device that could quickly spot brain injuries.

HEAD CHECK

ACCIDENT VICTIMS COULD BENEFIT FROM A NEW TECHNOLOGY THAT HELPS paramedics assess brain injury during the crucial first minutes after a blow to the head. Researchers at the Oak Ridge National Laboratory have developed a portable, noninvasive device that uses ultrasound to detect bleeding in the brain. Existing ultrasound technologies produce high-resolution images but require expensive equipment and highly trained personnel. This device, in contrast, doesn't produce an image at all: it simply compares how each side of the brain reflects ultrasound waves and alerts the operator if there are asymmetries or abnormal signals. "We're not trying to replace fancy imaging at hospitals," says Joel Mobley, a researcher who helped develop the technology and now works at the U.S. Army Research Laboratory in Adelphi, MD. "We want to give first responders critical information on what's going on inside the head, so they know where the patient should be taken." Oak Ridge's Tuan Vo-Dinh estimates that it will take one to three years to get the technology licensed and earn U.S. Food and Drug Administration approval.

LIGHT BOOSTER

A NEW DEVICE DESIGNED BY GARRETT Cole and Qi Chen at the University of California, Santa Barbara, could help bring fiber-optic connections—and the massive doses of bandwidth they provide—to home Internet users. The device is an inexpensive amplifier that could be used to boost data signals in the critical "last mile" of fiber-optic cable running between a home or neighborhood and the telecom backbone. One of the major hurdles in telecommunications has been the cost of existing amplifiers, such as the sophisticated devices used in the backbone. But the new amplifier can be fabricated the same way computer chips are, without any mechanical assembly, so it promises to be much cheaper. What's more, it's tunable, like a radio dial, so it can compensate for changes in light frequency that confound other inexpensive amplifiers. If a company were to show interest, says Cole, it should take only a few years to develop a commercial device.



Cheap, tunable optical amplifiers like these could help bring fiber-optic connections home.

INSPECTOR BOT

AN AUTONOMOUS ROBOT COULD SOON save businesses millions of dollars in the inspection of pipelines. Houston-based itRobotics is developing a robot that can travel tether-free, without operator intervention, for kilometers inside tubing and small-diameter pipes, making inspections cheaper and easier and detecting some flaws that aren't detectable from the outside. The trainlike prototype, designed for pipes five to six centimeters across, pulls one or more carts loaded with sensors that detect changes in, for example, magnetic flux, which can indicate wall thinning or cracks. The robot's proprietary locomotion system and onboard computer allow it to decide whether to proceed, slow down, stop, or even reverse. The company plans to introduce its first inspection robot, for the oil and gas industry, this fall. Future versions could inspect plant equipment such as the boilers and heat exchangers found in refineries, chemical plants, and desalinization plants.

This robot inspects pipes and tubes from the inside.

AUTOMATIC HIGHLIGHTS

Don't have time to watch your favorite team? At Microsoft Research Asia in Beijing, China, computer scientists Hongjiang Zhang, Yufei Ma, and Gu Xu have developed software that automatically generates highlight reels from video of sports programs. Import the video onto a PC, and computer vision algorithms recognize objects on the screen, like balls or people. The software then identifies key events, such as the ball going through a basketball hoop or into a soccer goal. "Sport has grammar," says Zhang, and the computer can use that grammar to organize its summary of a game's important plays. Related software can also edit TV programs into segments of interest, such as news and weather forecasts, so the viewer doesn't have to watch an entire broadcast. It's all still being tested, but Zhang says these features could be part of Microsoft home entertainment software within a few years—in time, perhaps, for the 2008 Olympics. Look out, ESPN.

COURTESY OF UNIVERSITY OF CALIFORNIA, SANTA BARBARA (BOOSTER); ITROBOTICS (BOT); OAK RIDGE NATIONAL LABORATORY (HEAD CHECK)

Interventional Innovation

POLITELY BUT VERY INSISTENTLY, THE TELEVISION ad asks if you or someone you know experiences nervousness and discomfort in social situations. Of course, *you personally* neither palpitate nor sweat in public places. But do you have a close and troubled friend who fits that description? Perhaps he or she should consider taking a special pill. ■ Or consider your aging parents. Their energy isn't what it once was, and keeping in touch across time zones is increasingly awkward. Having them on e-mail would be great. Alas, they're stubborn technophobes. You're not confident you can reliably get them online. What should you do?

While these simple scenarios involve provocative personal decisions, they also capture an essential innovation dilemma. When are innovators wiser to target their prospective users' perceived *communities of care* than the prospective users themselves? Getting people to do something innovative for themselves is one kind of challenge; persuading them to persuade other people to invest in novelty is quite another.

No, this isn't about marketing or encouraging word of mouth. This is about determining which "innovation vectors" make the most sense while making the most money. Children's advertising offers the paradigmatic example: kids see ads for innovations like new toys, breakfast cereals, and fast foods and relentlessly pester their parents to adopt them. Does the kiddie vector work? Of course it does. That's why governments in Europe and private advocacy groups in America want TV ads for tots radically restricted or abolished.

But the innovation imperatives separating kiddies from caregivers are profound. Children are unalloyed creatures of instant gratification; caregivers promote innovation as a medium for commitment and concern. Taken to its logical extreme, the community-of-care vector is about "innovation intervention": that is, an explicit effort to convince friends or relatives to adopt a particular innovation *for their own good.*

For innovators, caregivers may be a wiser target than the prospective users themselves.

That's why so many adult children of aging parents would like senior-friendly Internet setup packages offering, for example, one-touch access to e-mail and large-type screen displays. Would they pay a premium for such a service setup? Given longer life spans and the demographic tilt toward the elderly, that's a multibillion-dollar question.

No doubt the greatest opportunities in innovation intervention will be driven by biomedical breakthroughs. Social taboos that once made it impolite to tell friends or family members that they drank or smoked or ate too much seem to have collapsed. It's not difficult to imagine gift certificates for elective surgery such as liposuctions or post-pregnancy tummy tucks for moms who feel depressed that they've "let themselves go" after the births of their children.

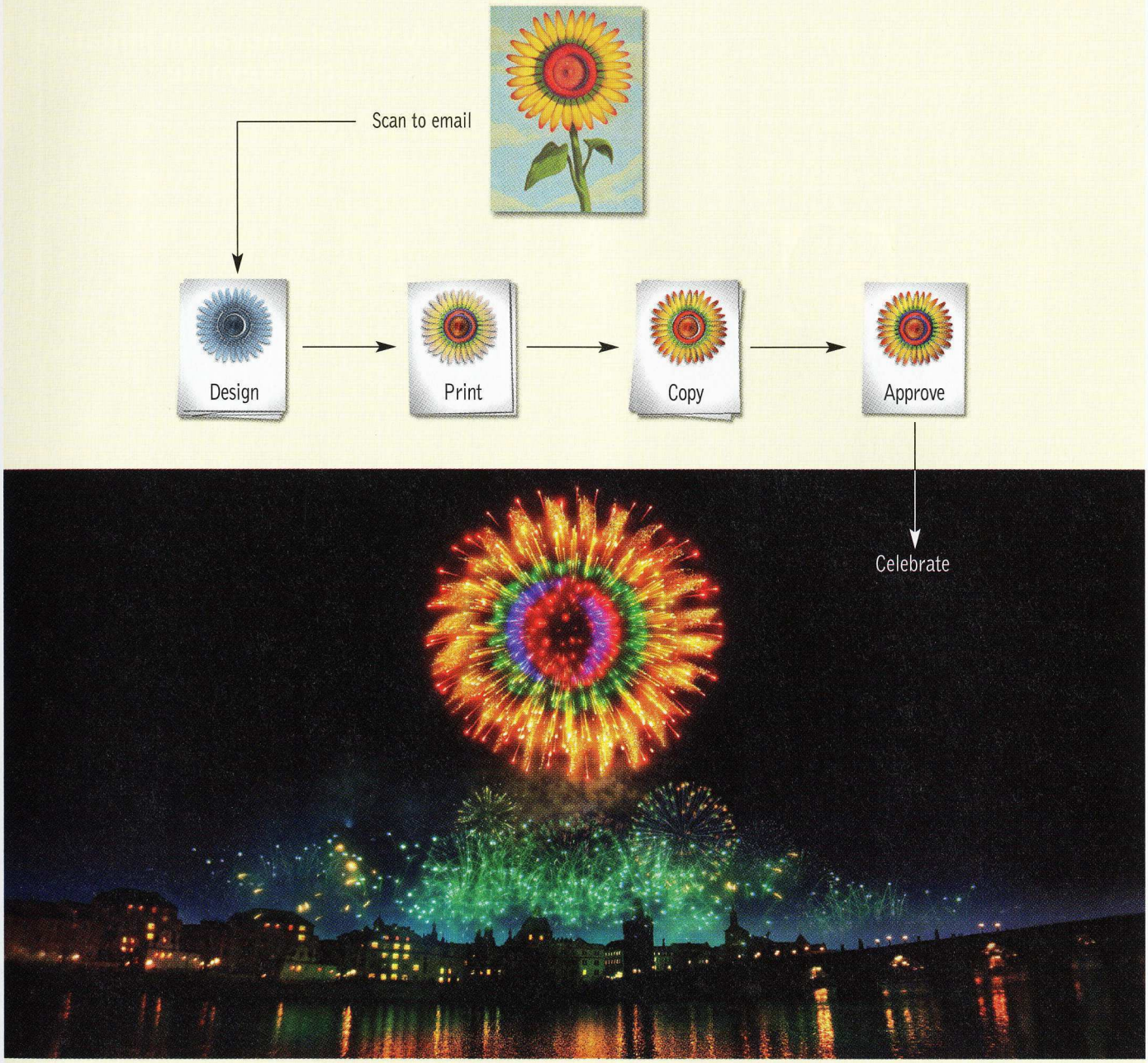
Similarly, the expanding array of antidepressants, antianxiety drugs, and other cognitive enhancers guarantees a fundamental rethinking of how innovative therapies are marketed. Alzheimer's medications are already targeted to caregivers. Indeed, how can people who increasingly suffer from short-term memory loss be expected to remember to take their medicine? But nowadays it's also common for schoolteachers to recommend that parents consider medication for their hyperactive or potentially ADD-afflicted children—for their own good, of course.

While debates about the ethics and efficacy of medicalizing an increasing number of once normal behaviors will no doubt intensify, the undeniable reality is that individuals—whether children, adults, or seniors—live in contexts that involve people who ostensibly care about them. These communities of caregivers are also marketplaces. And these marketplaces need their own support, education, and training infrastructures.

Innovators who invest as if these caregivers were simply salespeople for their innovative products and services are both fools and lousy businesspeople. Segmenting the innovation-intervention marketplace may prove even more economically important than segmenting the users of those innovations. If you're GlaxoSmithKline and you're touting a drug like Paxil as a remedy for anxiety among overextended professionals, for example, you'll probably want to tailor one message to employees' spouses and a very different one to a company's human-resources executives.

Yes, there's a core of presumptuousness in this pushy, do-goodery persuasion. But that's part of its charm and effectiveness. The innovations need to be robust and reliable enough to justify and support the intervention. They must be designed, packaged, and promoted with interventions in mind. Necessity may be the mother of invention, but if it's your mom who needs the invention, you'll be grateful for some innovative help in intervening. TR

A researcher and consultant on innovation economics, Michael Schrage is the author of *Serious Play* (Harvard Business School Press, 2000).



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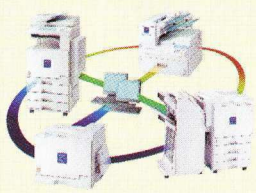

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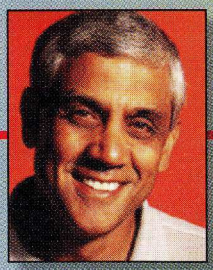
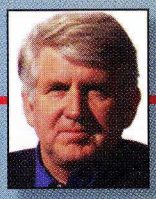


G. Richard Wagoner, Jr.,
Chairman and CEO, General Motors

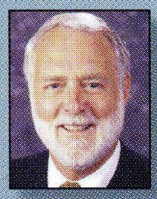
Ray Kurzweil, Founder, Chairman and CEO, Kurzweil Technologies, Inc.



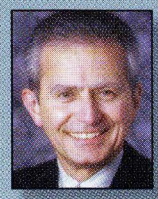
Bob Metcalfe, Founder, 3Com Corporation, and General Partner, Polaris Venture Partners

Michael Hawley, Director of Special Projects at the MIT Media Lab

The National Innovation Initiative Joint Keynote



G. Wayne Clough, PhD, President, Georgia Institute of Technology



Nicholas M. Donofrio, Senior Vice President, Technology and Manufacturing, IBM Corporation

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From Lab to Market: Where Technology is Headed – The Research Director's Point of View

Moderator: Rebecca Henderson, Eastman Kodak LFM Professor of Management, MIT Sloan School
Panelists: Uma Chowdhry, VP, Global Central Research and Development, DuPont
Paul Horn, Senior Vice President, IBM Research
Bob Tepper, President, Research and Development, Millennium Pharmaceuticals

Invention and Innovation: Emerging Technologies That Will Change the World, the Inventor View

Panelists: Steve Wozniak, Co-Founder, Apple Computer, and CEO, Wheels of Zeus (wOz)
Tim Berners-Lee, Director, World Wide Web Consortium (W3C)
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GE's new research lab in Garching, Germany, is the company's third lab outside the United States; the others are in Shanghai, China, and Bangalore, India.

COURTESY OF GE

GE: Green and European

The industrial giant's new Munich research outpost puts renewable energy in high gear

BY TOBIAS HÜRTER

Though still small potatoes compared to fossil fuels, renewable-energy technologies are experiencing explosive growth worldwide. Wind turbines, for example, are propagating at a greater rate than any other electricity-generating technology: global capacity surged 25 percent just last year. And Europe, with its high fossil fuel costs and generous government subsidies of "green power," is the epicenter of this growth, accounting for two-thirds of wind power facilities installed in 2003.

None of this has escaped the attention of General Electric, which is opening a new research center near Munich, Germany. The $52 million lab will largely be devoted to renewable-energy technologies, including hydrogen fuel cells, wind turbines, biomass fuels, and photovoltaics based on polymers. It will also develop the electronics needed to tame variable electricity sources like wind and solar for use in buildings and in the electricity grid.

"To see a company like GE buying into the idea that future power sources are going to be renewables—and invest the research dollars both in the U.S. and the European center—bodes well for all the renewable technologies," says Robert Thresher, a mechanical engineer who heads wind technology research at the U.S. National Renewable Energy Laboratory in Golden, CO.

The new lab, on the campus of the Technical University of Munich in Garching, Germany, is also helping crack something of a Berlin Wall that has long divided corporate and university research in Europe. The university recently began collaborating with GE, developing better agriculture-based fuels for gas turbines. "GE came at the right time," says Christoph Hirsch, a member of the university's combustion technology group. "German companies are more reluctant to work with academic researchers. And if they do, they often insist on tight nondisclosure and expect the state to fund the research."

What's more, through the Munich center, GE also aims to forge ties to local

industries. The company is negotiating with BMW to collaborate on hydrogen storage and hybrid engines and sensors, says Hans Bornemann, head of business development for the new lab.

It's all part of GE's strategy to dominate the market for renewable-energy technologies. Two years ago, GE bought Enron's wind business and expanded aggressively into the wind power market. Today, GE Wind Energy is one of the company's fastest-growing divisions and is heading for world market leadership, having picked up another 9 percent of market share from 2002 to 2003, according to BTM Consult in Denmark. And in March, the company acquired the U.S. photovoltaics manufacturer AstroPower and now sells complete photovoltaics systems for homes. "In ten years, we will rule the world," predicts Vlatko Vlatkovic, GE global technology leader for electronic and photonic systems.

The new center also reflects GE's renewed commitment to technology development in general. Since 2001, GE has invested $100 million in its Niskayuna, NY, research headquarters and built a $64 million research facility in Shanghai, China. While the Munich lab is focusing on renewable energy, which consumes about half of its research budget, it will also develop sensor, medical-imaging, and automotive technologies.

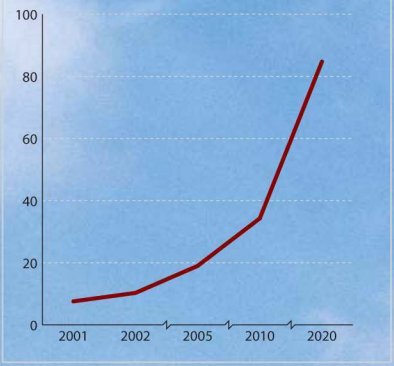
GE's aggressive research expansion in Germany brings the fight to its chief rival in the fields of power systems, medical technology, and lighting: Siemens. In fact, from Siemens's headquarters in Munich to the new GE research center north of the Bavarian capital is just a 20-minute drive. And GE's plans to research medical, sensor, and automotive technologies strike at the heart of Siemens's business.

But Siemens has made a strategic decision not to pursue core renewable-energy production technologies; rather, it supplies parts, consulting, and maintenance to geothermal power plants and wind farms. So at least for the time being, GE has the wind at its back when it comes to renewables.

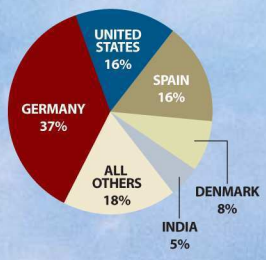
WIND POWER: TAKING EUROPE BY STORM

Wind power generation in Europe is expected to grow enormously in the next two decades. The industry estimates that wind power will account for 28 percent of all new electricity generation capacity in Europe between 2001 and 2010, and that by 2020, wind turbines will generate more than 12 percent of the continent's power.

By 2020, wind turbines in Europe are projected to produce enough electricity to supply 80 million households.

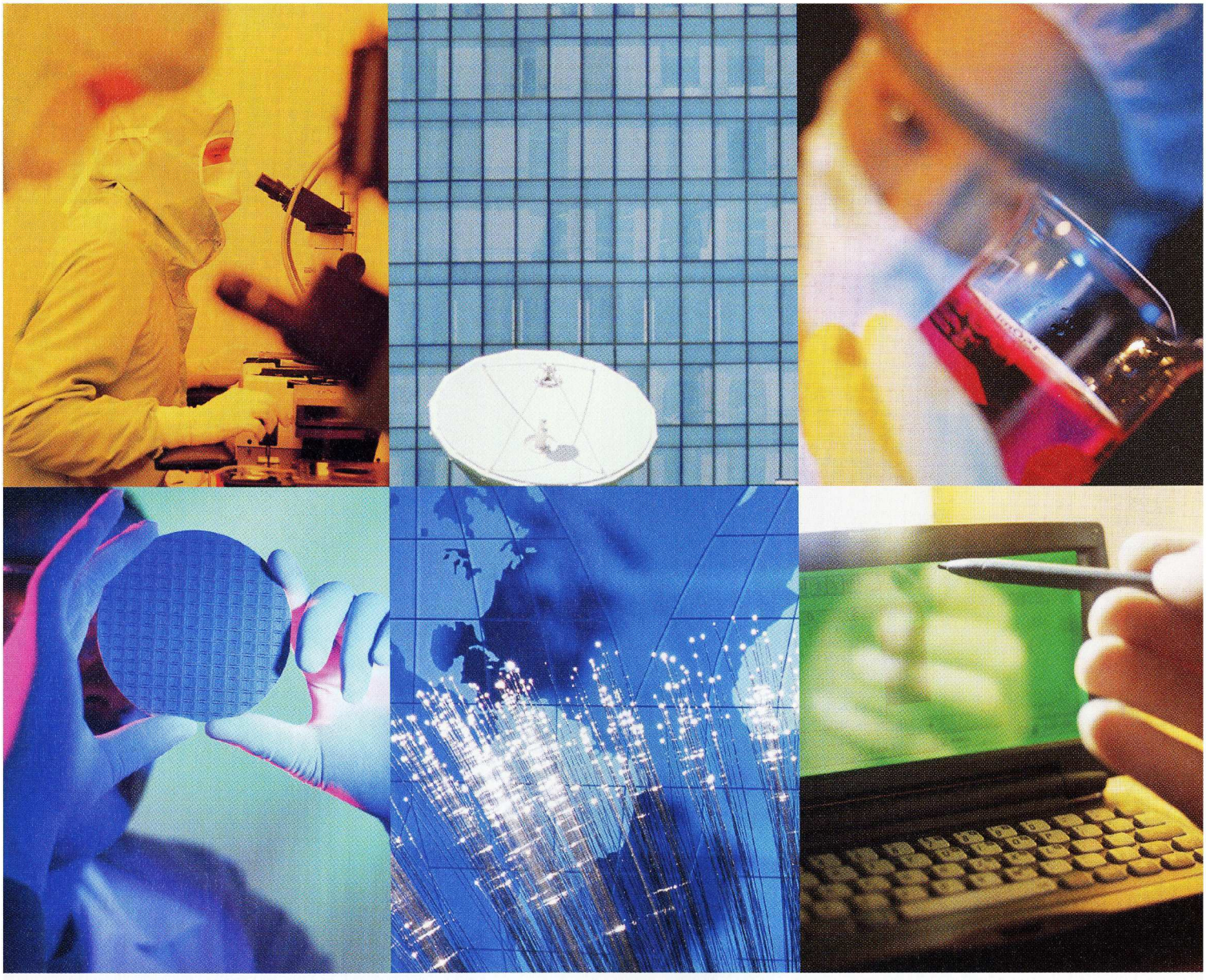


Today's wind turbine installations are concentrated in five countries. Their percentages of global wind-power production:



A new offshore GE wind turbine installation is visible from Arklow, Ireland.

SOURCES: WORLD WIND ENERGY ASSOCIATION, EUROPEAN WIND ENERGY ASSOCIATION; PHOTOGRAPH: COURTESY OF GE GLOBAL RESEARCH



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FOOD TECHNOLOGY

Fish-Oil Cookies

Drug-delivery tricks eyed for processed foods

Cookies and pasta taste the same despite a novel ingredient: encapsulated fish oil containing Omega-3s (powder, center).

COURTESY OF BIODELIVERY SCIENCES

How about some fish oil in your dessert? Fatty-acid nutrients known as Omega-3s, derived from certain fishes, are a hot commodity these days because of their putative ability to cleanse arteries. So food companies are mixing them into everything from milk to sports bars to boost nutritional—and marketing—value. Now they are also seeking ways to mix large amounts of Omega-3s into foods like crackers or tomato sauce that can't normally hide the fishy flavor—and in which the fragile oils more readily break down.

A number of companies are adapting encapsulation techniques already used in the drug industry. In processed foods, the techniques can preserve the fragile oils for months. BioDelivery Sciences of Newark, NJ, encases the fish oil in a calcium and soybean lipid matrix, the same approach it takes with antifungal drugs it has in clinical trials. Raphael Mannino, the company's chief scientific officer, says the technology works in everything from pasta to chocolate chip cookies and is already "under evaluation by a number of major food companies."

One company exploring nutrient encapsulation technologies is Kraft Foods of Northfield, IL, owner of brands like Nabisco and Oscar Mayer. Kraft says the widespread use of such technology is all but inevitable in the next few years. It is "the real new trend in the food industry," says Manuel Marquez-Sanchez, head of the Kraft Foods Nanotek research consortium, which funds university research. Any new food products containing fish ingredients would likely fall under U.S. Food and Drug Administration allergen-labeling requirements.

The market could be large. Healthcare analyst Bill Martineau of the Freedonia Group, a Cleveland research firm, estimates that the market for "functional" foods containing medically beneficial nutrients—which hit $23 billion in 2003—will exceed $40 billion in 2008. So what's good for you will also be good for the industry's bottom line. **Wendy Wolfson**

COMPUTING

Supercomputer Salvo

Two U.S. installations will boost science and surpass Japan

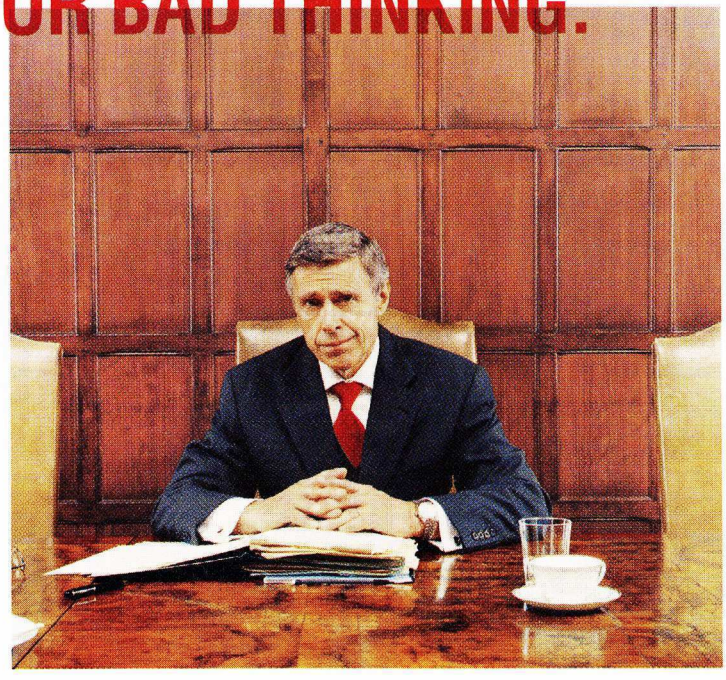
When Japan's Earth Simulator surged to life two years ago as the world's most powerful supercomputer, it heightened concerns that computing efforts in the United States were falling behind *(see "Supercomputing Resurrected," TR February 2003)*. The machine performs more than 35 trillion operations per second, or 35 teraflops, at its peak speed. Now, two contenders that will vastly outperform the Earth Simulator are waiting in the wings: a 360-teraflops IBM-built machine at California's Lawrence Livermore National Laboratory, scheduled for completion in 2005, and a 100-teraflops Cray system at Tennessee's Oak Ridge National Laboratory, due to be up and running in 2006, and possibly expanding to 250 teraflops the following year.

While the Lawrence Livermore machine will be used primarily to project how well materials in nuclear stockpiles age, the Oak Ridge system will be open to research proposals. Likely projects for the superfast computer range from simulated protein-folding experiments to research in nanotechnology, aerospace, and energy.

One possible payoff: carmakers could run computer models of crashes, reducing their reliance on expensive vehicle crash tests. General Motors alone spends $500,000 on each crash test.

The new, ultrafast computers will also be able to more accurately predict when a material is likely to crack, an insight critical to the safety of everything from aircraft to nuclear-power-plant reactor vessels. Current simulations model individual atoms in an area no more than a few micrometers wide for no more than a millisecond. With today's supercomputers, "You could never observe something as simple as ice melting," says Don Dossa, program manager for the Lawrence Livermore machine. The new machine, he says, will model atoms in an area thousands of times larger for nearly one second, helping explain phenomena that people can actually see, such as a crack forming. It's an advance that might seal the fissure in U.S. supercomputing. **Tracy Staedter**

"INNOVATIVE THINKING? WE DON'T EVEN HAVE TIME FOR BAD THINKING."



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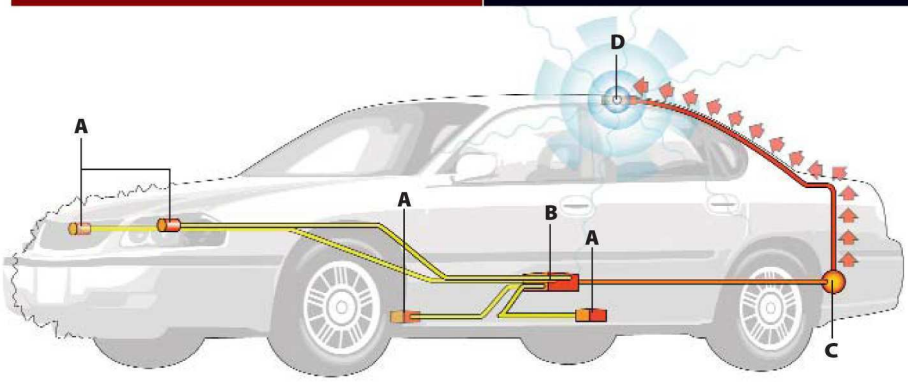


Wireless automatic crash notification starts with sensors already standard in many cars. Front and side impact sensors (**A**) detect crashes, while an accelerometer (**B**) determines crash severity. The data travels to a communications module (**C**) that broadcasts it via a roof-mounted antenna (**D**).

TELEMATICS

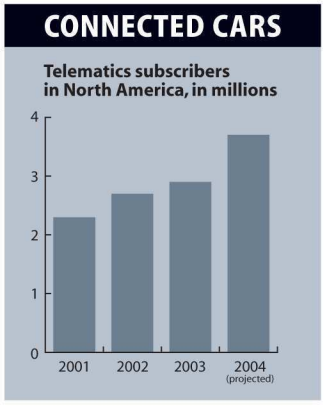
The Wireless Wreck

Cars gain ability to send crash data to police, hospitals

If you have an accident in one of the 2.5 million cars whose owners subscribe to General Motors' OnStar telematics system, air bag sensors and other collision detectors will trigger a wireless alert to OnStar's call center, where an employee can notify a 911 operator of your location. But in the next few years, far more data—including information on the force and direction of impact and whether the car has rolled over—will also be available. And this data will go not just to OnStar operators but directly to police and emergency room doctors, who can gauge the necessary emergency response and medical treatment even before the first squad car reaches the wreck.

OnStar is wrapping up tests of the turbocharged telematics technology in Minnesota. As part of the tests, detailed crash information is being sent electronically to OnStar call centers, which relay it to 911 operators, to select hospitals, and to state police dispatchers. According to Brad Estochen, project manager with the Minnesota Department of Transportation, the goal is to expand the test system by the end of the year, so that the data travels in real time to a Web server accessible by all hospitals, local police agencies, and other emergency responders in the state.

The system—which leverages the extensive data-collection already being done in cars—could save lives, claims OnStar. "You could potentially send advanced life support right away, versus having someone go there, assess the scene, and then call for advanced life support," says Jasmin Jijina, senior technologist in OnStar's Advanced Technology Group in Troy, MI. Wide-scale deployment will happen on a region-by-region basis, as individual police agencies and hospitals adopt the system over the next several years. So far, 13 states besides Minnesota are gearing up to start similar systems, says Estochen.



In ten years, nearly all telematics services will include similar advanced collision notification, predicts Frank Viquez, director of automotive research at ABI Research in Oyster Bay, NY. Eventually, such alerts could include additional information, such as the type of cargo on a jackknifed truck. And the news of a crash could feed into traffic notification systems, so other drivers could avoid problem spots. "We're just scratching the surface here," Viquez says. **Alyssa Danigelis**

COMPUTER VISION

Burger Profiling

Pull into the McDonald's in Chippewa, PA, these days, and computer vision software will tell the fry cooks what you probably want for lunch before you get out of the car. Over the past year, HyperActive Technologies of Pittsburgh has equipped eight fast-food restaurants in Pennsylvania and Ohio with cameras and software that analyze incoming traffic, providing a jump on likely food orders.

HyperActive's software counts cars as they enter, identifies the types of vehicles it spots, and makes recommendations based on past trends at the restaurant. Incoming minivans might foretell demand for chicken nuggets and other kid-friendly fare, while pickup trucks suggest double cheeseburgers or Quarter-Pounders. The program then estimates food demand for the next few minutes and transmits cooking instructions to display screens at the grills and deep fryers.

As a result, restaurants have cut customers' waiting time by as much as one-third and reduced food waste, says HyperActive cofounder R. Craig Coulter, a former computer scientist at Carnegie Mellon University's Robotics Institute. Pat Currie, a manager at Tri County Management, which owns the Chippewa franchise, says the system also reduced the stress on frazzled help. "It was beautiful," says Currie. "There was no yelling and screaming."

If HyperActive's figures are accurate, the technology has promise, says Andy Feinstein, a food-service-technology professor at the University of Nevada, Las Vegas. Fast-food restaurants are "all about volume," he says. "Anything that they can do to reduce waste, they would certainly work at."

Other companies are also enlisting computer vision in the fast-food cause. Advanced Interfaces of State College, PA, has recently conducted field trials with local McDonald's restaurants to map foot traffic, evaluate layouts and promotional displays, and help restaurants plan their menus for different times of the day or week. Which means your local burger joint might eventually know what you want days before you do. **Dan Cho**

SOURCE: ABI RESEARCH (CONNECTED CARS); ILLUSTRATION: COURTESY OF ONSTAR

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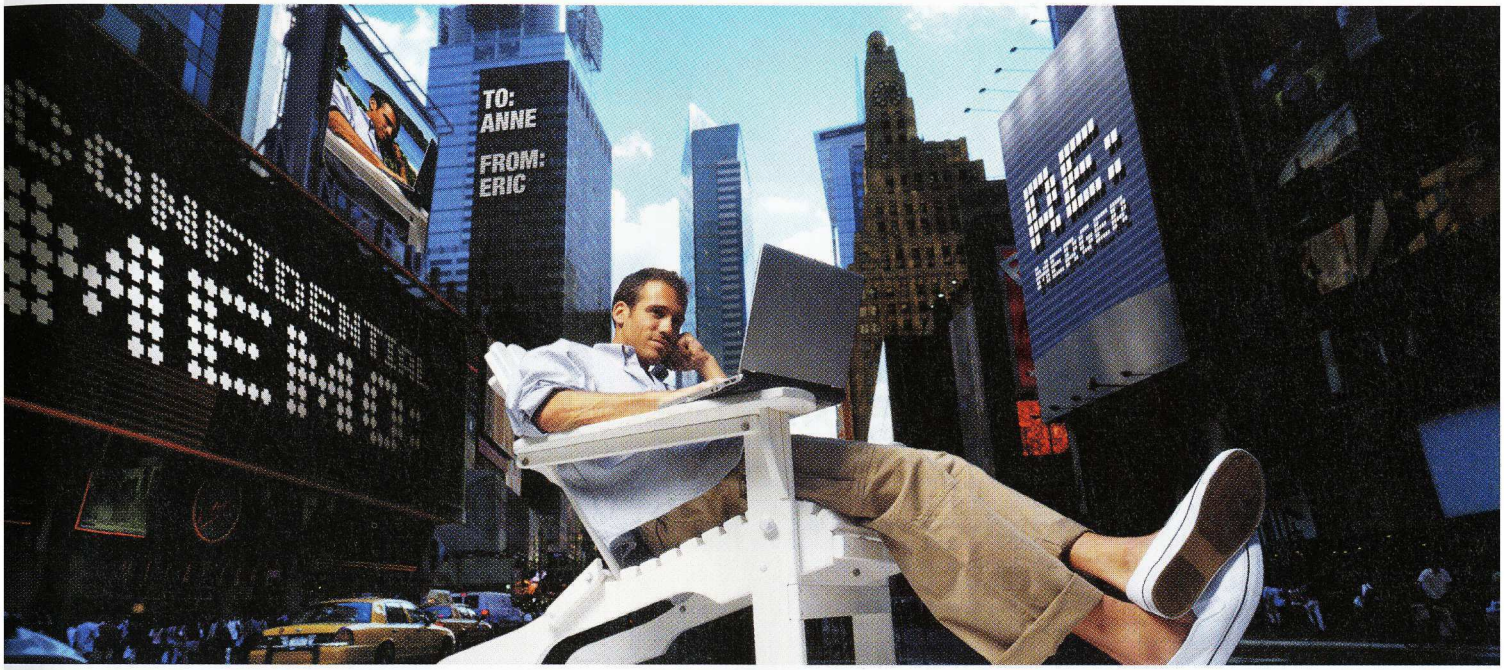

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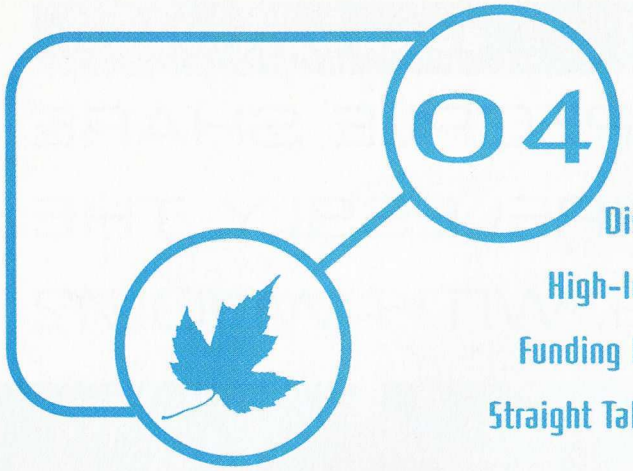

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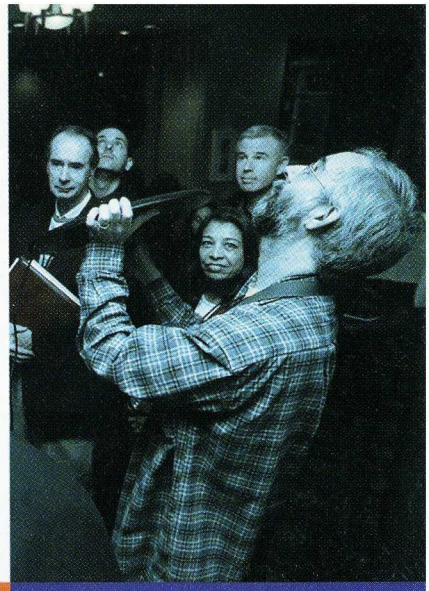

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Iogen's new factory will be a far larger version of this demonstration plant in Ottawa, Ontario.

ENERGY

Plant Power

First mass-production of ethanol from corn waste planned

While ethanol made from fermented corn grain can boost the octane and reduce the tailpipe emissions of gasoline, it's expensive, costing about five cents a liter more than gas. A Canadian biotech company, however, says that next year it will begin building the world's first facility to mass-produce ethanol, not just from grain, but from a far more abundant source: agricultural waste, such as cornstalks, cobs, and leaves. That could help bring ethanol's price closer to that of gasoline.

Iogen of Ottawa, Ontario, uses enzymes made by a genetically engineered fungus to convert cellulose in the corn waste to sugars, which are then fermented to make ethanol. Three sites in the United States, Canada, and Germany have been proposed for the new plant, which will produce about 200 million liters a year—a capacity similar to that of the largest existing ethanol plants—and should be operational by 2007, says Jeff Passmore, executive vice president of Iogen. A $54 million investment by Shell and Petro-Canada is making it possible.

Whether Iogen can actually reduce the cost of ethanol won't be clear until the factory is up and running, says Robert Anex, an agricultural engineer at Iowa State University. But what is clear is that using all of the waste from U.S. corn could theoretically increase the U.S. ethanol supply from about 11 billion liters a year to 95 billion liters, which is more than enough to blend with all U.S. gasoline at the current common proportion of up to 10 percent, says Charles Wyman, a chemical engineering professor at Dartmouth College.

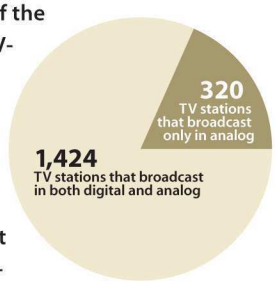
If Iogen succeeds, the chemical that gives zip to beer could help a lot more cars run cleaner. **Corie Lok**

WIRELESS

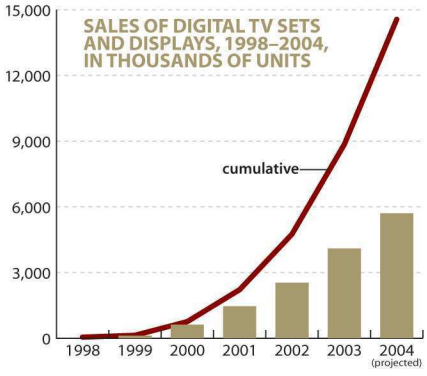
Fuzzy Outlook for Digital TV

When digital television finally takes hold in the United States, vital radio spectrum currently used by analog TV broadcasts will be reallocated to other uses, such as advanced wireless technology and emergency communications. The Federal Communications Commission is now slated to take this spectrum away from analog TV broadcasters as soon as 85 percent of households in each broadcaster's market own at least one digital set.

But the analog-to-digital transition isn't going entirely as planned. By the end of 2003, only 8 percent of the nation's 105 million TV-viewing households had bought digital TV sets. The government had hoped to hit the 85 percent threshold by the end of 2006; but now the FCC is considering a plan that lumps cable sets in with digital TVs, in order to reach the threshold by the beginning of 2009. At that point, holdouts who still cling to their old TVs and depend on over-the-air broadcasts will either have to sign up for cable or satellite service or purchase set-top boxes that convert digital signals to analog. **Wade Roush**



Eighteen percent of U.S. over-the-air broadcast stations have not yet added digital signals to their analog transmissions.



Despite steadily rising sales, only 8 percent of the nation's 105 million TV-viewing households had digital TVs by the end of 2003.

SOURCES: CONSUMER ELECTRONICS ASSOCIATION, NATIONAL ASSOCIATION OF BROADCASTERS, FEDERAL COMMUNICATIONS COMMISSION (DIGITAL TV); PHOTOGRAPH: COURTESY OF IOGEN AND BIO

Infote

advance

PointShot Wireless thinks people shouldn't have to go without Internet access just because they're riding trains. Installed in a railway car, the Ottawa, Ontario, company's RailPoint server connects to the Internet via cellular and satellite signals and relays data to passengers' laptops via Wi-Fi. PointShot is testing the service on lines between Toronto and Montréal and in northern California.

upgrade»

The **Roomba** vacuum cleaner from Cambridge, MA-based iRobot is already the most successful home robot ever, with more than half a million units sold since its 2002 debut. Now iRobot has made the $250 flying-saucer-shaped gadget smarter, adding a feature that causes the Roomba to linger over especially soiled spots and new software that automatically guides the device back to a charging station when batteries are low.

ipo

Now investors can get a chunk of **Freescale Semiconductor**, the former chip-making division of Motorola. The Austin, TX, company, a leading maker of processors for cars, cell phones, PDAs, and cellular base stations, raised $1.6 billion on the first day of public trading of its shares on the New York Stock Exchange on July 16.

gadget

Steve Jobs steadfastly declines to build a video version of the Apple iPod, so Microsoft and Creative Labs of Milpitas, CA, have done it for him. The **Zen Portable Media Player** has a 10-centimeter screen and a 20-gigabyte hard drive and plays video and audio files in Microsoft's Windows Media format. A similar device is expected from Samsung this month.

exit

Both **Yahoo!** and **America Online** have scrapped the business versions of their instant-messenger programs. Millions of U.S. workers have installed free instant-messaging software at the office to keep in touch with fellow employees, and the companies had hoped to charge employers $30 to $40 per user per year for centrally managed versions of the programs. Customers didn't bite. Left standing in the enterprise instant-messaging market: Sun Microsystems, IMLogic, IBM's Lotus division, and Microsoft, which recently announced technology that will let office workers send messages across the boundaries that separate the AOL, Yahoo!, and MSN instant-messaging networks.

milestone

The light-emitting transistor will be the focus of a new lab at the University of Illinois, where the versatile device was recently invented. Researchers at the **Hyper-Uniform Nanophotonic Technology Center** will work on improving and exploiting the transistor, which can pump out both electrical and optical signals in response to an input and could make it possible to replace the electrical wires in circuit boards with much faster optical pathways.

COURTESY OF CREATIVE LABS (GADGET); COURTESY OF IROBOT (UPGRADE); CHRISTOPHER HARTING (DIRT)

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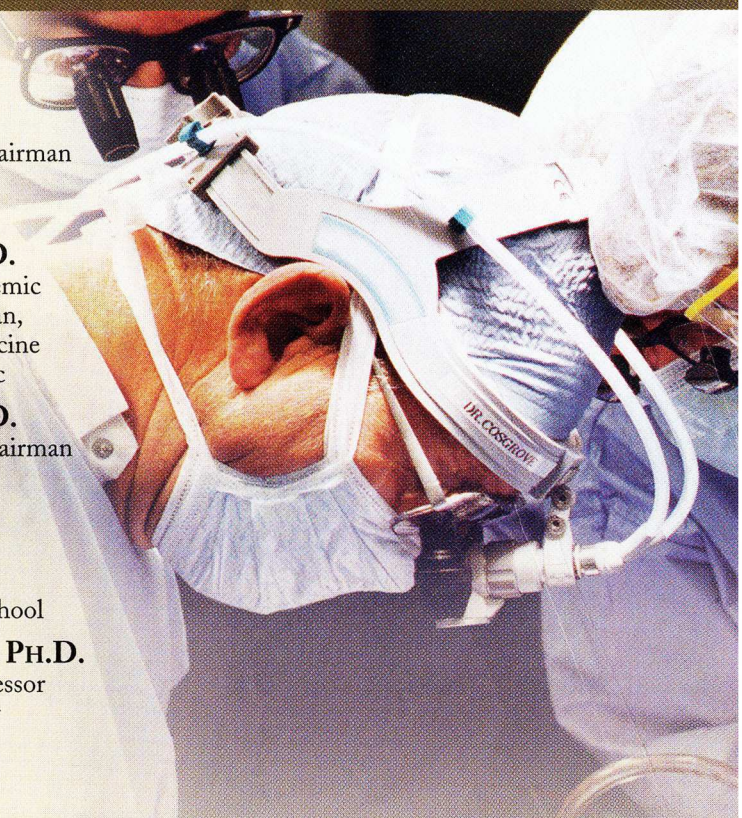

Join more than 800 industry leaders for the 2004 Cleveland Clinic Medical Innovation Summit, October 18-20. Industry leading CEOs, investors and clinicians will highlight new technologies, therapies and related economics in the unique setting of The Cleveland Clinic—a world leader in patient care, medical innovation and the #1 ranked Heart Center in America.

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funding

Citing the economic importance of the electronics industry, a group of CEOs from leading European companies has called for Europe's public and private investment in nanoelectronics to reach at least 6 billion euros ($7.4 billion) a year. Those signing the group's appeal include the CEOs of **Nokia** and chip producer **STMicroelectronics.**

milestone

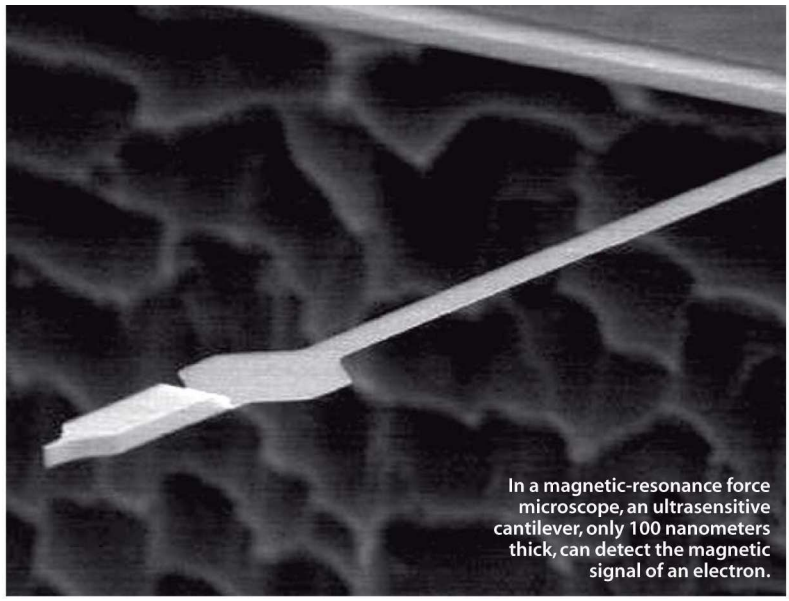
Researchers at **General Electric** say they have built one of the smallest functioning electronic devices ever, a diode made from a carbon nanotube. Diodes are widely used in electronics, and GE says its device could be vital to making future electronics even smaller and faster.

follow-up

Cheap and easy-to-make solar cells that use nanomaterials have the potential to revolutionize energy production. A leading startup in the field, Lowell, MA-based **Konarka Technologies**, which is developing flexible, printable solar cells *(see "Solar-Cell Rollout," TR July/August 2004)*, has raised $18 million in a new round of financing. The startup, which expects to introduce its first products by the end of the year, has raised $32 million since 2001.

advance

In the development of what could prove to be a fundamental new tool in nanotechnology, researchers at **IBM**'s Almaden Research Center in San Jose, CA, have built an instrument capable of detecting the "spin" of a single electron. The magnetic-resonance force microscope could open the doors to 3-D imaging of biological molecules and of the atomic structure of materials. The researchers say the new microscope combines techniques from magnetic-resonance imaging and scanning tunneling microscopy, which IBM Zürich scientists invented.



In a magnetic-resonance force microscope, an ultrasensitive cantilever, only 100 nanometers thick, can detect the magnetic signal of an electron.

investment

German chemical giant **Degussa** is beginning construction on a nanotech R&D center in Marl, Germany. The company says it will spend 50 million euros ($62 million) on its new Nanotronics Science to Business Center over the next five years. Startup is scheduled for 2005.

Nanot

patents

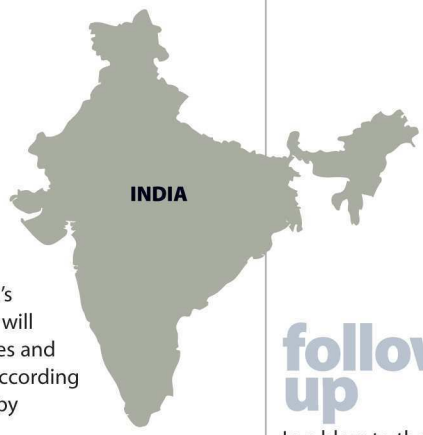
Carbon Nanotechnologies claims that it now has a strong patent position in "all process routes currently considered to be practical" for making single-wall carbon nanotubes, the most important form of the pipelike molecules. The company, a Rice University spinoff cofounded by Nobel laureate Richard Smalley, received its latest patent for a process for growing carbon nanotubes on a catalyst. Carbon nanotubes are one of nanotech's most promising materials and have applications in making everything from tiny transistors to superstrong fibers.

CHRISTOPHER HARTING (FOLLOW-UP); COURTESY OF IBM RESEARCH (ADVANCE)

initiative

In a move that could facilitate drug discovery, the **National Institutes of Health** has thrown its weight behind the nascent field of chemical genomics with the launch of a new research center. Chemical genomics aims to understand how "small molecules"—the type of compound found in most drugs on the market today—interact with all the proteins encoded in the genome. The NIH Chemical Genomics Center's goal is to study more than 100,000 small molecules within its first year; as many as 10 additional centers will join it in an NIH-funded chemical-genomics consortium by late 2005.

forecast



Over the next five years, India's burgeoning biotech industry will generate $5 billion in revenues and more than one million jobs, according to a report recently released by **Ernst and Young**.

follow-up

In a blow to the already battered field of gene therapy, Alameda, CA-based **Avigen** announced that it has discontinued its human trials of a gene-based treatment for hemophilia. The trials were once viewed by researchers in the field as a chance for gene therapy to redeem itself after a spate of prominent failures *(see "High Stakes for Gene Therapy," TR March/April 2000)*. Halting them was part of Avigen's decision to refocus its R&D on neurological disorders.

Biote

collaboration

General Electric has forged a joint research collaboration with **Celera Genomics Group** and **Celera Diagnostics**, the latest in a series of moves by GE to strengthen its focus on personalized medicine and imaging. In their first project together, the companies will develop new cancer-imaging agents that target cancer-associated cell-surface proteins identified by Celera Genomics.

ipo

In July, Berlin-based **Epigenomics** raised about 42 million euros ($5 million) in its initial public offering on the Frankfurt Stock Exchange. Founded in 1998, Epigenomics is developing a host of cancer diagnostic tests based on its ability to detect DNA methylation—a sort of molecular on/off switch for genes.

advance

Beijing, China's **Sinovac Biotech** has begun the first test of a SARS vaccine in humans. Over the course of the 210-day test, 24 volunteers will receive the Sinovac vaccine, one of several under development around the world. If the vaccine proves safe in this trial, Sinovac will have to conduct larger human studies to show that it effectively blocks SARS infection.

PETER PARKS/GETTY IMAGES (ADVANCE)

MEGABYTE:

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IT LOOKS LIKE A LARGE-SCALE SCULPTURE, IN WHICH leaning steel towers are fused with elements that resemble brick warehouse buildings, a bright yellow kiva, crushed soda cans, and a blindingly silver beached whale with a smokestack in its center. This spring, MIT's Computer Science and Artificial Intelligence Laboratory moved into a new building—but not just any new building. We moved into the $300 million Ray and Maria Stata Center, created by the often controversial postmodern architect Frank Gehry.

What are a bunch of researchers who pride themselves on rock-solid research, journal publications, and startup companies like Akamai and Peppercoin—all based on deep mathematics and solid value propositions—doing in a building that looks all flair? Some of us are not at all sure. But I view this as a wonderful experiment: make everyone just a little uncomfortable and see what their squirmings lead to.

MIT's new Gehry-designed center is itself a wonderful experiment, one that will likely drive fresh approaches to research.

The first things that surprise people when they walk into the Stata Center are the dazzling amount of light and the confusion between inside and outside. Exterior shapes and surface materials cut through glass ceilings and walls and suddenly appear inside as well. Glass is everywhere—two floors below you or four floors above you—and bright primary colors on the walls reflect light, light, and more light.

Another thing that surprises people is that it's hard to tell whether the building is finished. Many of the walls are made from plywood bolted to rough metal frames, which extend above head height with no covering. Rough concrete columns and stairways here and there make it feel as if there is still more construction to be done. But the building is, in fact, finished.

Frank Gehry took our desires for flexible space very literally. And he was also inspired by the stories of Building 20, which formerly occupied the Stata Center site. Building 20 was constructed in 1943 for the Radiation Laboratory, which conducted top-secret wartime development work on radar.

Later, it housed generations of laboratories and academic departments—among them the Research Laboratory for Electronics and Noam Chomsky's linguistics department (Chomsky has an office in the new building, too, high above us in the Dreyfoos tower). Building 20 was so temporary in nature that its occupants felt no inhibition whatsoever about taking up hammer and saw to remodel their individual research spaces as needed.

Gehry endeavored to give us the same sort of flexible space, which we will mold and change over time to suit our purposes. Some people are fantastically happy with everything just as it is. Surprisingly (at least to me), others who have made a career out of tearing down old ideas and replacing them with avant-garde new ones are a little shocked by a confrontation with a physical space that they don't quite understand.

Faculty members are responding in a variety of ways. One has in his office the same desk he was first assigned at MIT as a freshman 40 years ago. Another put a beautiful hardwood floor atop his raised floor and outfitted his office in the Italian Liberty style.

Graduate students have been even more aggressive in their responses. Some immediately painted glass walls near them to gain privacy. Others reveled in the open space and moved their desks next to each other so they could work in teams. The many lounges scattered throughout the building all seem well used, and students have created new semiprivate lounges in the middle of research spaces. Couches to sleep on day and night have appeared throughout the building—some hidden, others visible from three floors away.

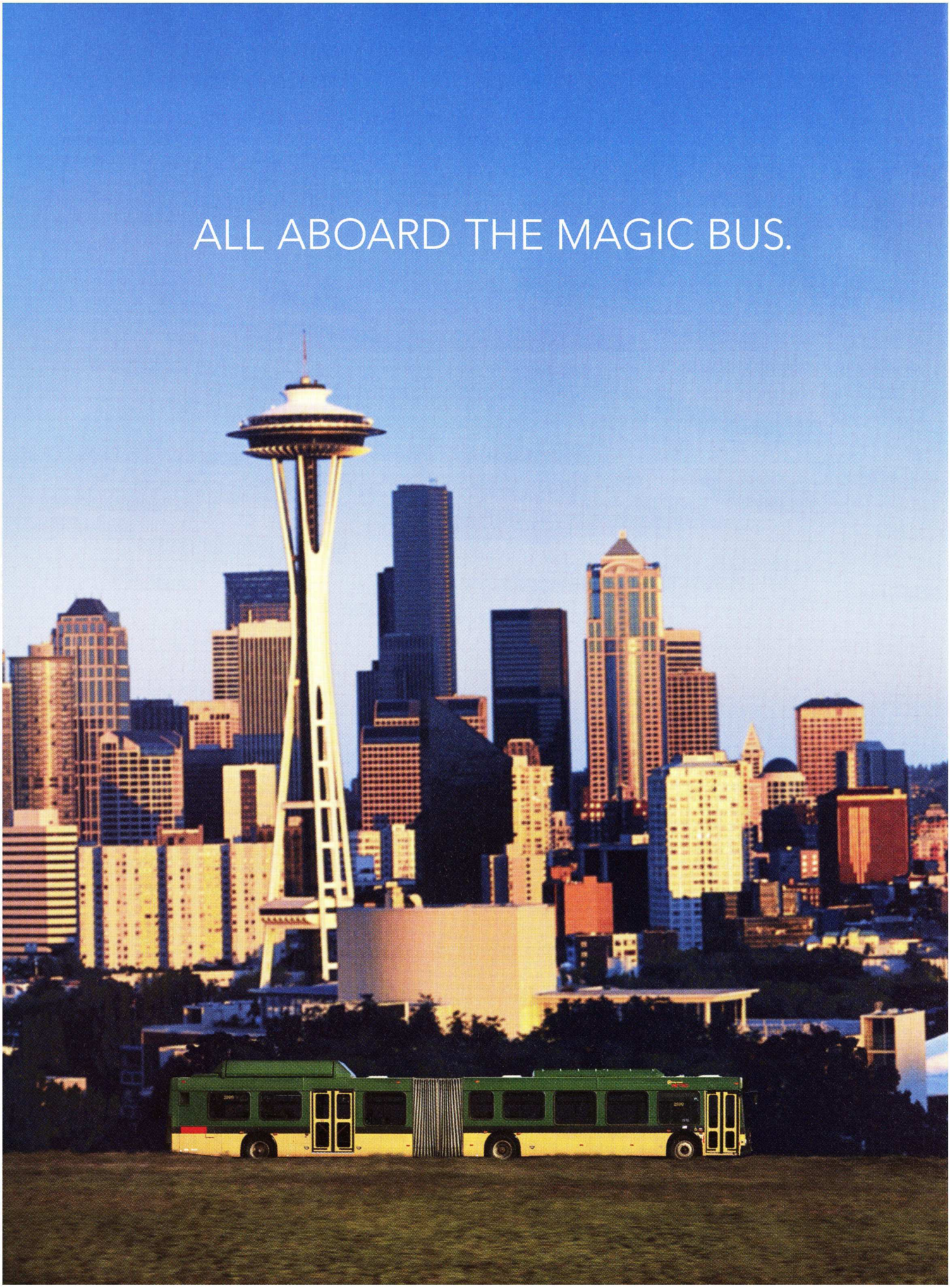
Many faculty and students view the building as a perfect engineering challenge. New touch screens, tastefully encased in plywood boxes to blend in, have rapidly appeared near elevators so that visitors can look up their hosts or identify what seminars are in which strangely shaped rooms. If you have one of the latest cell phones in your pocket, maps and location data get automatically downloaded as you walk past one of these kiosks.

Some researchers have dispatched robots to wander the corridors and build perfect three-dimensional maps of the building's interior. I've warned them to be careful showing their results at conferences: their audiences may think the curved and sloped walls and complete lack of 90-degree angles reflect errors in their software.

While all of us perpetually relish the chance to confront hard problems, to gain exposure to new ideas, and most of all, to generate those new ideas, Frank has given us a disturbing new challenge. He has given us a mind-bending new spatial environment. I'm pretty confident that the next generation of MIT students will love this challenge, and that they will turn it into fresh new approaches to research.

And I can't wait to see what they come up with.

Rodney Brooks is director of MIT's Computer Science and Artificial Intelligence Laboratory.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Some call Miguel de Icaza a sellout.

But the Mexican open-source firebrand says the best place to continue the battle against Microsoft is within a big corporation.

By David H. Freedman

PHOTOGRAPHS BY JOHN GOODMAN

Rebel within a company: Open-source crusader Miguel de Icaza sold his startup company to the staid business-software vendor Novell, in Waltham, MA.

THERE'S A SENSE OF dissonance in the office of Miguel de Icaza. On one hand, here is the celebrated hacker—as in programming whiz, not virtual trespasser—wearing a T-shirt, looking boyish and rail-thin, and resembling an impoverished graduate student who has been living on coffee. But here also is the vice president of product technology for staid software giant Novell, entirely at ease as he takes command of a plush corporate conference room in Cambridge, MA, with a view of the Charles River and the Boston skyline. It's a dissonance, however, that de Icaza is quick to wave away. "There are a lot of motivations in the open-source community, like the freedom to choose software platforms and the chance to innovate," he says, referring to the global community of programmers who write software that others are free to download and modify. "Now one of my motivations is that I'm being paid to do this, and I have to deliver products."

Both determinedly idealistic and stubbornly pragmatic, de Icaza is in many ways the new face of the open-source software movement. A programming firebrand, de Icaza has rocketed in stature in just a few years from an unknown student at a Mexico City university to one of the leaders of the increasingly successful challenge to Microsoft's hegemonic grip on computing. And though he remains deeply connected with the community of idealistic programmers who make open source possible, his meteoric rise is fueled in large part by a keen marketing sense. De Icaza recognized early on that to be truly popular with everyday users, the Linux operating system—the freely available operating system that serves as open source's alternative to Windows—needed the same icon-based bells and whistles familiar from the Windows desktop and access to applications of the same variety and quality as those that run on Windows machines. Open source might offer cheaper and better software, but de Icaza instinctively recognized that it would only change the world if people actually used it.

Indeed, nothing better illustrates the surprising evolution of open source than de Icaza's trajectory over the last eight years. Starting as an unpaid programmer who contributed minor software programs that supplemented Linux, de Icaza cofounded a startup company called Ximian in 1999 to bring Linux-based desktop tools to market. The company quickly became a major player in the open-source movement, and last year Novell, a financially troubled software vendor best known for its corporate networking products, bought the startup.

Novell hopes to use open source to stop the hemorrhaging of its customer base. Novell's once vaunted Windows-oriented corporate networking software had been waging an increasingly vain battle against Microsoft's own products. "We were losing 10 to 12 percent of our base every year," says Hal Bennett, Novell vice president for business development. "We needed a bright new place to go." Novell hitched itself to the one approach making headway against Microsoft: open-source software. "Open source is starting to look like the future to a lot of people, and Novell desperately needed a future," says Rob Enderle of the market research firm Enderle Group in San Jose, CA. "Open source and Linux gives Novell a road map that appears credible."

What's most significant about de Icaza's move to the corporate world is that it's not unique. "In some ways Miguel has been a totem for those of us in the open-source community," says Michael Shaver, an open-source project leader who recently joined Oracle Software. "He's gone from bits of hacking to dealing at a high level with both corporate and community interests. And that's similar to the direction the entire open-source movement has followed."

SMASHING WINDOWS

De Icaza's story, like those of most programmers active in the open-source community, has been closely entwined with the story of Linux. Linux appeared seemingly out of nowhere in 1991 when a Finnish student named Linus Torvalds posted the first version of it on the Web, offering PC users a way to escape what many saw as Microsoft's tyranny. Up until that point, the open-source movement had been relatively tiny, struggling to put an operating system together piece by piece. With the appearance of Linux, the community had a viable, working alternative to Windows.

But there was a catch: using Linux required typing out arcane commands. Eliminating these commands is where de Icaza would make his mark. In 1991, he was an 18-year-old mathematics student at the National Autonomous University of Mexico—Mexico's Harvard. De Icaza couldn't afford a PC, but he had access to the university's computers and soon stumbled onto the suddenly thriving online world of the open-source community—a series of bulletin boards on which a sort of rebel alliance of hackers posted programs built on the freshly posted Linux platform and swapped extended barbs on everything from code to politics.

De Icaza soon made a name for himself writing a file management program for Linux, and by 1997 he had come to the attention of Microsoft, which flew him to its headquarters in Redmond, WA, for a job interview. According to Nat Friedman, a then intern at Microsoft and later a cofounder of Ximian, de Icaza took the interview as an opportunity to lecture managers on why Microsoft should abandon its multibillion-dollar business model and embrace open-source programming. Not surprisingly, de Icaza wasn't hired. Instead, he returned to Mexico City to launch the project that would strike at the heart of Microsoft's business.

The project was called GNOME, and it set the audacious goal of giving Linux a graphical interface as easy to use as the Windows desktop, thereby rendering Linux a legitimate alternative for everyday users in businesses and the home *(see "The Linux Revolution, Part II," p. 50)*. In 1997, a few hundred open-source programmers around the world flocked online to join de Icaza. By 1999 an initial version of GNOME was complete, and it was

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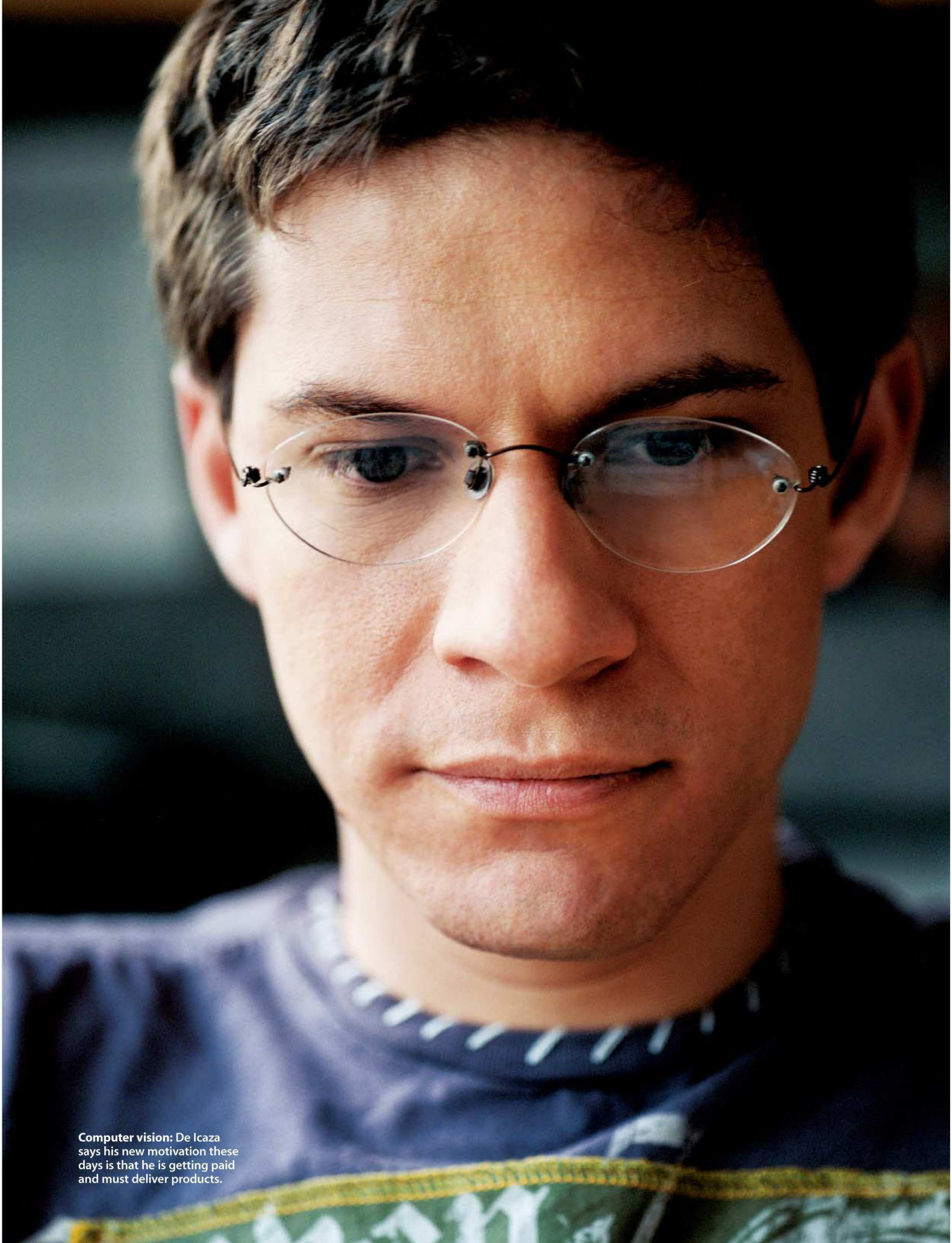

Computer vision: De Icaza says his new motivation these days is that he is getting paid and must deliver products.

soon adopted by tens of thousands of users, as well as by Hewlett-Packard, Novell, Red Hat, Sun Microsystems, and other companies. (De Icaza was named TR100 Innovator of the Year by *Technology Review* in 1999.)

GNOME had established de Icaza as not only a top-notch coder but also as someone with a keen eye for the big project and a knack for getting people on board. "I enjoy working on open-source software, but I particularly enjoy working with Miguel," says Todd Berman, a software developer at Medsphere Systems, a health-care infotech company in Aliso Viejo, CA. "He's a visionary, and he has a way of keeping things fun." De Icaza, says Oracle's Shaver, has a "terrifying talent for finding the right people and getting a project to critical mass."

Later in 1999, Friedman suggested to de Icaza that the two of them start a software company. Ximian was aimed at providing Linux users with the sort of application software that Windows users take for granted—tools like e-mail programs and online calendars, as well as software that helps information systems managers at companies keep employees' computers running smoothly. For most people, getting a fledgling company up and running would have been enough. But about a year later, de Icaza was already on to his next big thing. Tapping many of the GNOME programmers and using Ximian as a base, de Icaza plotted the launch of open source's ultimate assault on Microsoft's dominance.

WIDER NET

De Icaza explains the project with a story about a cornflakes box. The box advertised a computer game inside, written, of course, to run only on computers that used the Windows operating system. "I realized no one's going to write a game in a cornflake box for Windows, Mac, and Linux," says de Icaza. "And that's what keeps people using Windows today—a large selection of applications that aren't there for Linux." Popular programs like Word, Excel, PowerPoint, and Photoshop, for example, as well as the vast majority of computer games, are not designed for Linux. For typical PC users, Linux places favorite programs out of reach.

That problem was likely to get far worse, since Microsoft had designed a complex set of software building blocks called .Net, with which the majority of new software designed to run on networks is being written. Keeping Linux users from being shut out of this new universe required a set of programming tools that in essence would translate software written for Linux into .Net and vice versa. Such tools would let Linux users take advantage of new software written for Windows, while Linux programmers could sell their new software—for example, next-generation open-source versions of Photoshop and PowerPoint—to the giant Windows market. This proliferation of choices would inevitably drive down the price of software. De Icaza launched a project to come up with these new tools. He called it Mono, Spanish for "monkey."

Ximian raised $15 million in venture capital by the beginning of 2001 to pursue both the new tools and Linux application software and was bringing in steady revenues by helping companies develop and use open-source software. A handful of larger companies had approached Ximian about a possible acquisition, and that had gotten de Icaza thinking: maybe he could reach his goals faster as part of a big company. "When you're a startup, you don't have the resources to get software deployed quickly and to support it," he says.

But de Icaza inevitably ended up disappointed with the companies that came calling, mostly because of what he perceived as their lack of commitment to open-source software. Then, early last year, on the day de Icaza was starting a much needed vacation in Brazil, Friedman called him to say that Novell executives were coming to Cambridge the next day. "I said, 'God, not another meeting that doesn't go anywhere,'" de Icaza recalls. But he flew back and gave a presentation about Mono.

Some at Novell call de Icaza a "bohemian invader" but say that the greatest benefit Novell got from his company was not its technology but its DNA.

Novell had long ago ruled the lucrative world of networking software—the programs that help computers talk to one another, now ubiquitous at companies and becoming common in homes—until Microsoft usurped the throne. Novell's executives sensed a way out of their predicament in remaking the company's product lines as open-source programs. Mono would then be a jewel in its crown, allowing Novell's customers to move freely between open-source and Microsoft-based applications. It would make even Microsoft-dependent companies free to use Novell's open-source products.

The acquisition was announced in August of last year. But since Mono remains an open-source program that anyone can work on or modify, there are still a hundred or so programmers around the world who continue to work on the project on a volunteer basis. In some cases the volunteers do it because it gives them a chance to garner major-project experience that enhances their résumés, and in other cases they do it because they want to make sure the software meets their needs. Novell will profit from the results, not by selling the basic software, but by charging for embellished and integrated versions with service and support.

Reconciling Ximian's and Novell's very different cultures, meanwhile, wouldn't be a slam dunk. "To integrate the companies, we had to let go of our culture of independence," says de Icaza. "We didn't want to be considered a small research facility in Novell. If Ximian had a cool-hacker reputation, then our job was to help make Novell cool." Matt Asay, Novell's Linux business office director, concedes that it took Novell employees a while to get used to "this Bohemian invader," as he calls de Icaza. "People were uncomfortable at first," he says. "But you walk around now, and the pendulum has swung the other direction. People are giddy with the prospects for open source. I would say that the greatest benefit that Novell got from Ximian was not their technology; it was their DNA."

REBEL SELLS

To some in the open-source software community, de Icaza is a fallen angel—a legendary hacker who has strayed from the good

Linux suits up: Ximian had a cool-hacker culture; now it's doing its best to make Novell at least partly cool.

and pure. One gripe within the community: Mono enlists code that appears dangerously similar to .Net code heavily patented by Microsoft. More generally, some worry that de Icaza represents the breakdown of the once strong barrier between open source and the corporate world. In fact, Microsoft has apparently come to deeply regret spurning de Icaza back in 1997. Microsoft software architect Don Box even wrote a song imploring de Icaza to join the company and sang it to him in front of a large audience at a party late last year. But even though he didn't heed Box's siren song, de Icaza has essentially been accused of selling out to the corporate world.

The notion of being a sellout doesn't precisely amuse de Icaza, but he doesn't seem put out by it, either. "There's always some anticorporate fanaticism, but it's a tiny minority," he says. "Even back when I was working on GNOME, I knew companies would have to get involved. If you want to get all the benefits of the software, get rid of bugs, deploy it in real solutions, and bring it to a wide market, then you need big companies."

There have, of course, been a few drawbacks to going corporate. De Icaza sometimes has to stagger in for early-morning marketing meetings, though for the most part he has been able to maintain his customary work schedule of noon to 2:00 A.M. More importantly, says de Icaza, his new job has given him the best of both worlds: the freedom and shared passion of the open-source world, backed by the deep pockets and long-term strategy of a large corporation. "We were at the mercy of VCs at Ximian," he says. "We were constantly adjusting to whatever their latest idea was. But at Novell I'm thinking about what's going to happen over the next seven years."

If de Icaza seems to have left behind open source's rebel personality, maybe it's because he had a different revolution in mind all along. Having himself grown up in a country where most people can't afford computers, de Icaza has long championed the open-source movement as a means of bringing affordable computing to poor communities. "I've got a global goal," he says. "I want to make Linux successful on the desktop for countries where people can't afford computers with proprietary software." And while GNOME is already helping make Linux usable to less affluent computer users, Mono aims to ensure that those users will also have access to new generations of Web-enabled software.

If Mono achieves its goal, then Linux and other open-source programs are likely to continue to gain favor at the expense of Windows. Microsoft might then very well lose its long-standing domination of the computing world altogether, which would likely lower the cost of computing and, theoretically, provide more and better choice in software. That, at least, is the open-source vision. But revolutions seldom go according to plan. To know how the odyssey of de Icaza, and his fellow open-source programmers, will turn out, you'll just have to stay tuned.

David H. Freedman is a freelance writer based in Needham, MA.

Linux is finally offering Windows users a real choice.

By Wade Roush

ILLUSTRATION BY BILL MAYER

Will it always be a Microsoft Windows world? That's what I hoped to find out when I sliced open the box containing the new PC I'd ordered from WalMart.com. It had a respectable 1.6-gigahertz processor, a serviceable 40-gigabyte hard drive, a CD-ROM drive, an MP3 player, and enough other software to keep me occupied for life, though supporting it all was a barely adequate 128 megabytes of RAM. Okay, I knew this chunky black box wouldn't be the sexiest PC on my block. But that was fine, considering its paltry $278 price tag—and that I'd really ordered it for what it *didn't* have: any Microsoft software whatsoever. Rather than Windows and Office, it came with Linspire 4.5, one of the many commercial versions of the open-source Linux operating system that are

now available, and a link to a website where I could download a variety of open-source applications. ■ When I plugged in my Wal-Mart machine and hit the power button, I got a look at an alternate future that ought to be fueling Pepcid sales among Microsoft executives. The computer featured a glamorous new desktop screen and sophisticated control panels, help menus, and audio tutorials. I was instantly able to connect the machine to the Internet, where I downloaded—free of charge—open-source equivalents of the Microsoft Office programs I use every day: Word, Excel, PowerPoint, and Internet Explorer. The free software may not have all of Office's bells and whistles, but the version of it I chose, Open Office, does everything I need it to do—including saving files in Word format.

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The back-office world of servers and databases is no longer Linux's most exciting frontier. Sure, Linux has gained an irreversible hold in behind-the-scenes corporate computing centers, where some 67 percent of corporate Web servers are Linux machines running open-source software. Companies from Schwab and Merrill Lynch to L. L. Bean and Pep Boys have converted parts of their back-office operations to Linux, and IBM, Oracle, and other companies are spending millions to make their own business software run on the operating system. But over the last three years or so, the capabilities of open-source software have finally caught up with those of Microsoft applications in the space where most human-computer interaction actually occurs: the desktop. "For the user who spends 50 percent of the time in the Web browser and another 40 percent in the mail client, the Linux desktop is already there," says Andy Hertzfeld, an open-source programmer famed for his work on the original Apple Macintosh operating system.

True, Microsoft still commands 94 percent of the market for PC operating systems. But Linux is gaining fast. Software that gives a Linux machine the look, feel, and functions of a Windows PC is available both in free, unsupported versions and in souped-up commercial versions from a growing group of companies such as Novell, Red Hat, Sun Microsystems, and Lindows, the company that makes the Linspire system. In Toronto, customers can walk into the world's first retail Linux store, Sub500.com, and walk out with a Linspire workstation for as little as $222. Over the last three years, the fraction of home and office PCs powered by Linux has roughly doubled, to almost 3 percent, and it's set to double again before the end of 2005, according to market research firm IDC. Linux's market share has already surpassed Apple's, and every 1 percent gain for Linux sucks millions of dollars a year out of Microsoft's revenues. Much of that money stays in the pockets of businesses and consumers *(see "Open Source Sizzles," this page)*.

And while Microsoft isn't panicking, in an April presentation to financial analysts, the company put Linux and noncommercial software at the top of a list of "key business risks" that could affect its earnings in the coming years. To control those risks, Microsoft is pursuing a variety of tactics, including launching an anti-Linux marketing campaign and sharing some of its own source code in an effort to keep programmers interested in developing Windows applications.

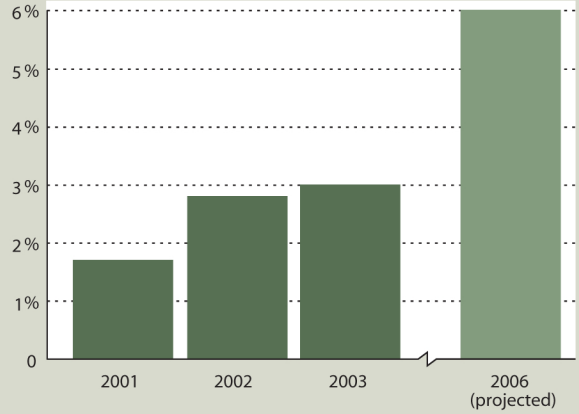
67
Percentage of corporate Web servers that are Linux based

But whatever Microsoft does, the flowering of open source on the desktop seems certain to change the balance of power in personal computing. Linux's availability is already driving price reductions—even for Windows machines—that are opening up computing and the Internet to millions around the world who would otherwise be unable to afford PCs. Inside businesses, open source is helping IT departments cope with today's smaller budgets and freeing up money that can be reinvested in new technologies. And for home or office users, open source offers a range of free, often innovative desktop applications that aren't available for Windows.

It's all enough to have Linux proponents feeling a little cocky. Jokes Eric Raymond, a Malvern, PA-based programmer who leads a nonprofit open-source standards group called the Open Source Initiative, "The sinister plan for world domination is right on schedule."

Open Source Sizzles

Percentage of operating systems shipped by commercial vendors that are Linux based.



SOURCE: IDC

THE OPEN OFFICE

You probably already use Linux more than you realize. Every time you run a search at Google or place a bid at eBay, for example, you're tapping into databases spread across thousands of Linux servers. In 13 years, the software has come a long way from the dorm room in Finland where Linus Torvalds, then an undergraduate at the University of Helsinki, built on ideas borrowed from AT&T's Unix operating system—and on the work of the GNU open-source project—to create something faster and more streamlined than either Unix or Windows. Torvalds invited other programmers to copy, use, and improve his offering, as long as they agreed to share any changes they might make, and he has been the movement's unofficial regent ever since, approving every new line of code.

But while Linux started out as a program written "for hackers by hackers," in Torvalds's words, that era is long past. Torvalds himself is now paid by an industry consortium, the Open Source Development Labs in Portland, OR, to oversee Linux's evolution. And the typical open-source programmer, apparently, is no longer a passionate hobbyist but a full-time professional at a company that either publishes or uses open-source software. At IBM, for example, 7,500 programmers are making the company's business software run on Linux, which many customers see as more reliable and less virus prone than Microsoft's products. Former networking company Novell recently purchased Ximian, a startup founded to build desktop Linux components *(see "The Linux Revolution, Part I," p. 44)*. "The more we have embraced the market, the more vigorous our culture has gotten," says Raymond. The result: improvements in Linux's capabilities that have facilitated wide adoption by business.

But that, as my Wal-Mart box testifies, is just the beginning. After all, every one of the 187 million new PCs that will be purchased this year (at a cost of some $213 billion, according to research firm Gartner) needs an operating system and produc-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tivity software. Creating easy-to-use, point-and-click interfaces for Linux and open-source applications has become "the one goal that everybody wants to achieve," says Andrew Morton, Linus Torvalds's second-in-command at the Open Source Development Labs. And that goal is now close enough to convince many organizations that it's time to switch.

OpenOffice is a core reason for the ascension of the Linux desktop. Based on initially proprietary software that was later made open source by Sun, it includes a word processor, a spreadsheet program, a presentation builder, and an image editor and has become one of the most popular open-source alternatives to Microsoft's productivity software. Companies such as Novell and Red Hat distribute it along with their own versions of Linux, and Sun sells an enhanced version called StarOffice. The key feature of OpenOffice is that it behaves pretty much the same way users of Windows software would expect—which means that any number of people could, in principle, become Windows defectors the next time they or their companies buy new computers or upgrade aging software.

LEANING TOWARD LINUX

Exactly how many of the people junking their old Windows machines will actually switch to Linux boxes? That depends on which group you're talking about. First there are the casual home users: those who use their computers mainly to surf the Web and exchange e-mail and the occasional digital photo with friends and relatives. "They are going to look for the lowest-cost machine available to them," says Dan Kusnetzky, vice president of systems software research at IDC. Several existing Linux-based programs, such as OpenOffice, "would be more than sufficient in that category," he says.

Another group ripe for migration to the Linux desktop is corporate employees who use their office computers for just one or two tasks throughout the day. "Help desks, call centers, IT departments, receptionists, shipping and receiving—jobs where all somebody needs is a browser and Web-based e-mail—that one-third of your people could go to Linux today," says Stuart Cohen, CEO of the Open Source Development Labs. And that's a substantial one-third: U.S. call centers alone employ 2.9 million agents.

If lower software costs are attractive to corporate executives, they're doubly so to government managers, another growing constituency for open-source desktop software. In cities as small as Largo, FL, and as large as São Paulo, Brazil, governments are saving millions by choosing Linux and free productivity programs over proprietary desktop software *(see "Going Global," p. 56)*. Other organizations and government agencies opt for Linux because they'd rather not hitch their futures to a single software company—especially a foreign company. In China, for instance, the State Council has instructed government ministries to buy Chinese-produced software the next time they upgrade their desktop systems, a mandate that is expected to be a big boost for Red Flag, China's leading Linux distributor. In June, the city of Munich, Germany, affirmed its decision to switch 14,000 city-owned desktop PCs from Windows to versions of Linux supplied by IBM and Novell, even though Microsoft had offered discounts worth millions of dollars. "It's not so much an anti-Microsoft feeling as it is not wanting to be dominated by an American company or by any one company," believes Matt Asay, director of the Linux business office for Novell.

60
Percentage of Microsoft revenues that comes from desktop and office software

By some estimates, one-third of office workers could switch to cheap Linux-based software today—
without noticing any difference.

There's one more big draw for Linux adopters: wider access to innovation, meaning software that Microsoft doesn't sell or hasn't gotten around to finishing. One open-source project called Dashboard, for instance, ties together disparate types of information desktop users juggle every day; it monitors whatever you're doing on your computer and plumbs your e-mails, appointments, contact lists, and file folders for related items, automatically linking to them from a box that appears at the side of the screen. Microsoft developers have talked about including such features in the much anticipated successor to Windows XP, code-named Longhorn, but commercial delivery remains two or more years away. Says Louis Suárez-Potts, project coordinator and business manager in Berkeley, CA, for the OpenOffice project, "Open source is the ticket out of the banality Microsoft has imposed."

THE EMPIRE STRIKES BACK

In the software industry, those are fighting words. Until now, Microsoft has had little reason to get stirred up about Linux's gains, which have come largely in the business server market and largely at the expense of Unix and Sun Microsystems' Solaris operating system. But the markets for desktop operating systems and office software—which together bring the software giant more than 60 percent of its revenues—are Microsoft's to lose, and both sides know it. "The outfit that runs 94 percent of the [desktop] space believes correctly that it can't live with us," says Raymond. "It's us or them, and we want to make sure it's us."

In public statements, Microsoft officials still downplay the open-source threat to Windows and Office. "Quite frankly, we're not seeing evidence that Linux or open source is making significant traction in the corporate desktop market," says Alan Yates, Microsoft's senior director of business strategy.

The company's actions, however, bespeak a much higher level of concern: it has begun slashing prices and even mimicking the open-source movement's own tactics, opening up portions of its closely guarded code to outside inspection.

In Thailand, for example, where Linux PCs from Thai firm Laser Computer are the top-selling brand, Microsoft last year cre-

ated stripped-down, Thai-language versions of Windows XP Home Edition and Office XP and offered them as a bundle for about $37—about one-sixteenth of their combined U.S. retail price. The company is trying similar markdowns in Malaysia, another Linux stronghold, and is considering offering cut-rate software packages in other developing countries.

While there's no talk of Thai-style price reductions for Windows software in the United States, WalMart.com does offer a PC with Windows XP Home Edition for $298, and Microsoft has launched a major publicity campaign asserting that the cost of retraining and support means switching to Linux and open-source applications is actually more expensive than sticking with Windows, especially for large organizations. Microsoft's recent moves add up to an acknowledgement that the company must now compete—and perhaps even coexist—with the open-source movement. "There is no one correct way to create software," acknowledges Jason Matusow, who directs Microsoft's Shared Source Initiative, a two-year-old program under which more than a million software developers and corporate customers can view—but not copy or redistribute—the code behind Windows and 16 other programs.

187 MILLION
Number of new PCs that will be sold in 2004

Matusow says Microsoft's limited form of open source helps customers integrate their own in-house software with Windows and brings Microsoft developers more direct feedback about bugs and needed features, but without giving away the company's core asset: its intellectual property. He believes that the proprietary and open-source software worlds can exist in symbiosis, with the open-source community supplying innovation that commercial software companies can later turn into marketable products. "We will vigorously compete with products that compete with us," says Matusow. "But it would be an absolutely unfair statement to say that we'd like to see [open source] go away."

Going Global

Around the world, governments are turning to the Linux desktop because it's cheaper and does not tie them to a single vendor. Some examples:

UNITED STATES In 2002, officials in Largo, FL, replaced aging desktop terminals used by 1,000 city employees with 400 Linux-based machines, a move that saves the city $1 million per year over the cost of Windows desktops.

EUROPE Last year, officials in Extremadura, Spain, a poor rural province, finished installing 80,000 new Linux-based PCs in schools and community centers, saving $21 million.

SOUTH AMERICA Last year, the low cost of Linux-based computers allowed the São Paulo, Brazil, city government to set up 20 PCs in each of 100 free Internet cafés across the city.

OPEN-SOURCE DÉTENTE?

Matusow's conciliatory message is lost on Raymond, who says that he's convinced the software giant's real agenda is to crush Linux. But while his anti-Microsoft belligerence is widely shared in the open-source community, others in the movement foresee an eventual accommodation between the two sides, especially as Linux wins major customers in government, education, and developing countries. Microsoft is "too well run, too smart a company," says Cohen of the Open Source Development Labs. "They will look at the market-share data, and at some point the needle will hit a number where they'll say, 'This is big enough that we are not going to fight it; we are going to participate.' Exactly how, I think they are still trying to figure out."

Might Microsoft produce versions of Office that run on Linux, as it did for Apple's Macintosh OS X? Will it suddenly open-source the code for major portions of its operating system and office applications and fall back on income from its server software, its home entertainment products, its online services, and the network-based services in which it has been investing heavily? The company says it has no such plans, and outcomes like these are hard to imagine, given Microsoft's heavy financial dependence on Windows and Office. But the company's current course—staking much of its future on the next version of Windows, when some of the improvements being discussed are already part of free open-source programs such as Dashboard—has its own risks. "I don't think people will wait forever for Longhorn," says Andrew Aitken, managing partner at the Olliance Group, an open-source consulting firm in Palo Alto, CA.

Especially not when they can get adequate power from inexpensive, non-Windows machines like my Wal-Mart box. The reality is that there is finally a viable alternative to Windows and Office, and that's guaranteed to reshape the landscape of personal computing. The only questions, at this point, are how far and how fast the open-source desktop will spread—and how much Microsoft will have to change to keep up.

Wade Roush is a *TR* senior editor based in San Francisco.

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Translating Iceland's Genes into Medicine

Iceland's **deCode Genetics** has spent eight years pursuing an ambitious mission: to collect and analyze a country's worth of DNA and turn that genetic insight into drugs. Now the company's efforts are on the cusp of paying off, as its first drugs near the market.

BY CORIE LOK PHOTOGRAPHS BY JOSHUA PAUL

Icelandic DNA donor: Benedikt Arnason and thousands of his compatriots across the island had their DNA analyzed by deCode Genetics.

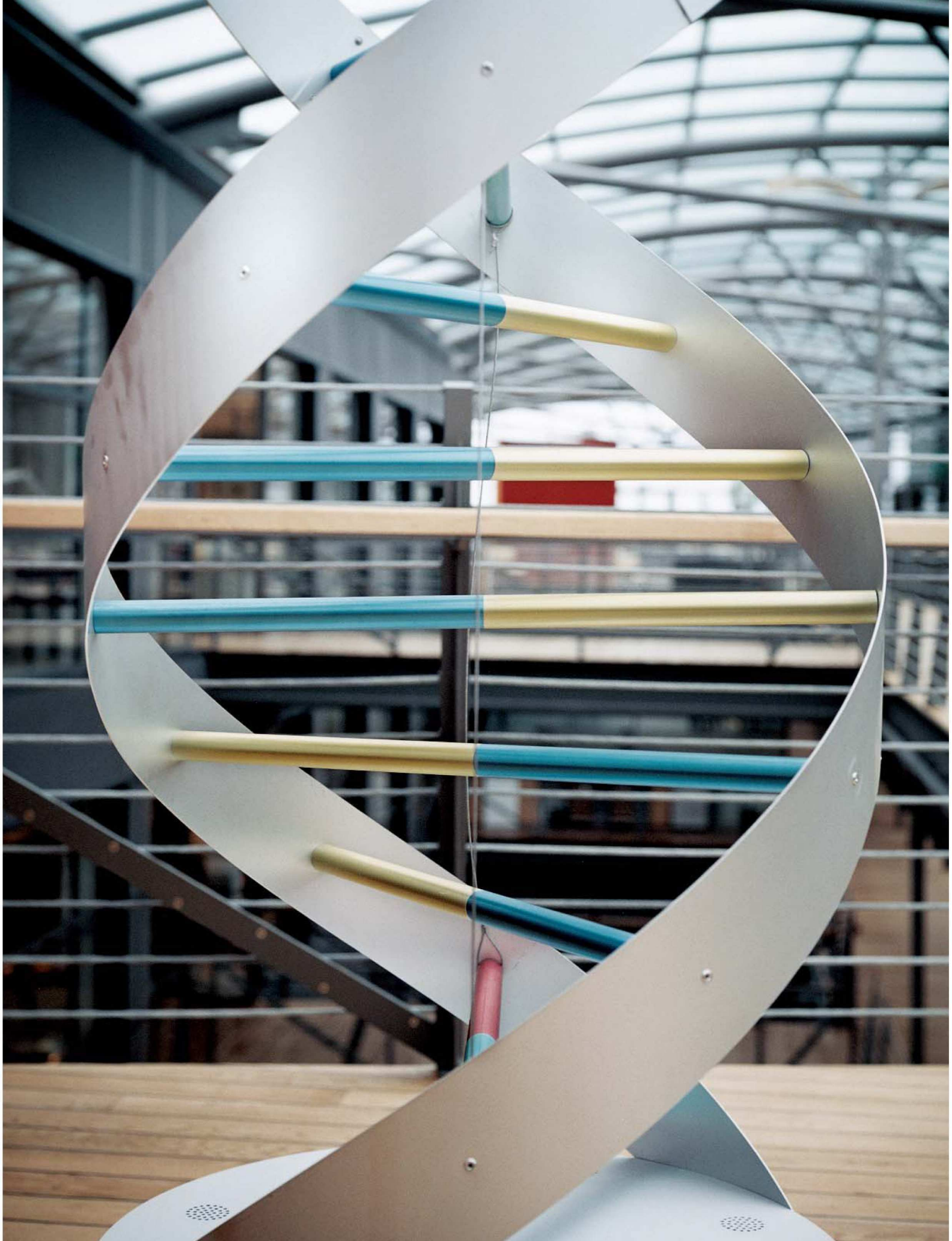
All in the family: Studying DNA from Icelandic families like that of Benedikt Arnason (fourth from left) is a cornerstone of the drug development efforts headed up at deCode's modern Reykjavik facility (opposite page).

RECLINED IN A CHAIR at a clinic outside Reykjavik, Iceland, Benedikt Arnason tells the story of the day, 11 years ago, that he had a heart attack. In a deep, rich voice cultivated by years as a stage actor and director with Iceland's national theater, he describes the chest pain that gripped him after one performance. He got to the hospital just in time. "The last thing I remember is the doctor asking me about my medical history," Arnason says. When he woke up, he found burn marks across his chest. Doctors had shocked him back to life. Now Arnason comes every two weeks to this suburban clinic, so doctors can monitor his progress as a participant in a trial of a new experimental drug—one that physicians hope might spare him from having a second, and possibly deadly, heart attack.

If it works, Arnason will have a whole nation to thank, as well as the vision of one of the world's most ambitious biotech companies. Three years after Arnason had his heart attack, deCode Genetics, which is headquartered in a modern building just a 10-minute drive away from the clinic, embarked on a nationwide hunt for the genes that underlie heart disease, diabetes, asthma, and other common ailments. The company was betting that if it could identify those genes by rifling through this tiny country's genetic heritage, it would gain critical clues about how to fight the diseases they cause. Eight years later, the tests on Arnason and other Icelanders suffering from heart problems are allowing the company to take the final steps in proving that its bet was correct.

The tests' success would mean not only deCode's first marketable medicine and a better heart attack drug but possibly the advent of a new generation of treatments based on a mastery of genetics. "We have been able to make more sense out of the genetics of common diseases than I think any other group in the world," says deCode's founder and CEO, Kari Stefansson. That has led to a handful of drugs, including one for peripheral artery disease, that are nearing the end of the development pipeline right behind the heart attack medication, which could be on the market before the end of the decade. DeCode is also working with pharmaceutical giants Roche and Merck to develop more drug candidates, even as it beefs up its internal drug-development capabilities.

There are, of course, no guarantees that deCode's first drugs will make it through human tests. But if they do, the repercussions could be felt far beyond this remote North Atlantic island. If Stefansson and his team succeed, they will be providing not only hope for Arnason and countless other sufferers of common diseases but also real-world evidence of genomics' power to transform medicine.



POPULATION POWER

On the surface, Iceland—a windy, almost barren island tucked just below the Arctic Circle—seems an unlikely place for a leading biotech company. But Icelandic scientists had recognized, long before the arrival of deCode, that their country is a good place for population-based medical research. For one thing, it has good medical record-keeping, and a self-contained population that doctors can easily reach through a high-quality, universal health-care system. DeCode was able to find Arnason, for example, because he was listed along with more than 8,000 other people in the national hospital's registry of all the Icelanders who had had heart attacks before the age of 75 between 1981 and 2000.

The Icelandic population also has a general openness to medical research. About 110,000 Icelanders—more than half of the island's adult population—have given their DNA to deCode, making genetics a sort of national science project. This cooperation, along with healthy investments in genetic data-mining software and DNA-reading technologies, has been instrumental in turning deCode into a gene-hunting powerhouse. In fact, Stefansson says, it has provided the company with enough data to tackle not just heart disease but 50 different ailments, ranging from asthma to diabetes to cancer. "This is a business in which critical mass is important, and they have achieved critical mass," says David Altshuler, a population geneticist at Harvard Medical School.

To understand just how powerful deCode's approach can be, consider the company's discovery of the gene it believes contributed to Arnason's heart attack. In theory, researchers could home in on such a gene by sequencing each heart attack patient's entire genome and looking for frequently recurring gene variants, but with 30,000 genes and three billion letters of DNA to sift through per patient, that would be far too time consuming and expensive. So instead, deCode started by looking for a chromosome region likely to harbor the genetic culprit. The approach was fairly straightforward: deCode analyzed a limited number of key markers spread out along the chromosomes of heart attack victims and used them to identify chunks of chromosomes that were more highly shared than other chunks. "You can think of it as something rather magical, in the sense that you don't need in advance to know what genes to look for or to have anything to tag the genes with," says Augustine Kong, deCode's lead statistical geneticist.

DeCode was aided in this process by another unique Icelandic resource: a plethora of publicly available genealogy records—church records, censuses dating back to the 1700s, even ancient stories describing the island's settlement by Vikings in the ninth century. When launching a study like the one on heart attacks, says Kong, "We put the list [of patients with the disease] and the genealogy together, and we use that to identify the patients who are related." Since people who are related share longer stretches of DNA than those who aren't, Kong says, choosing clusters of relatives allows deCode to use only about 1,000 markers to find a suspect chromosome region, making the approach more cost effective. Conducting a similar hunt with unrelated patients' DNA would require a million markers, Kong estimates.

High-tech, low-tech: DeCode has brought large-scale gene hunting to this quiet country still dependent on natural resources such as fishing and animal agriculture. DeCode's headquarters (middle panel) is a few blocks away from quaint downtown Reykjavik (middle left panel).

Once deCode had used this approach to narrow its search to a section of chromosome 13, the researchers compared the heart attack patients with a group of people representing the general population. A more detailed analysis of the differences between the two groups enabled deCode to zoom in further, to an area small enough to contain just one or two genes.

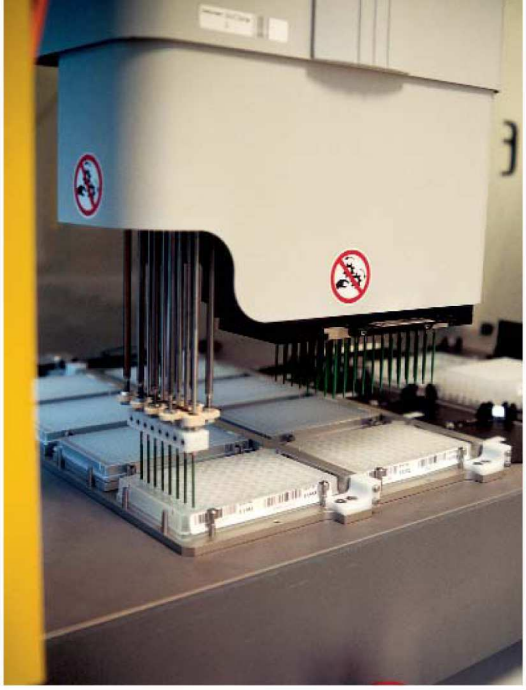
Now tantalizingly close to their goal, the researchers turned to public gene databases to find out what genes had already been traced to that spot. When they saw that the stretch of DNA was home to a gene that codes for a protein involved in inflammation—a process implicated in heart disease—they knew they were onto something. Cardiologists believe that when "plaques"—fatty deposits in arterial walls—get inflamed, they are more likely to break away, form blood clots, and cause heart attacks. DeCode found that Icelanders like Arnason who have a specific variant of the chromosome-13 inflammation gene have double the normal risk of heart attack, perhaps because the variant is an overactive version of the gene and causes excessive inflammation. Blocking the protein encoded by the gene, deCode researchers reasoned, might keep the plaques from getting as inflamed, so they would remain safely attached to the arterial wall. In other words, the protein might make an excellent target for a drug.

Such scientific understanding is still a huge step away from having a drug in hand, though. The deCode researchers still needed to find a compound that could safely hit the target. But

POPULATION EXPLOSION

A sampling of other population-wide DNA-banking and analysis projects

INSTITUTION	PROJECT
Estonian Genome Project (Tartu, Estonia)	Analyzing Estonian blood samples to find genetic and environmental disease factors; goal of collecting 100,000 blood samples by 2007
Galileo Genomics (St. Laurent, Québec)	Using the DNA of a proposed 40,000 Québécois to look for genes associated with asthma, arthritis, schizophrenia, Crohn's disease, and other ailments
Oxagen (Abingdon, England)	Analyzing 40,000 blood samples, primarily from northern Europeans, to develop drugs for inflammatory diseases such as asthma and rheumatoid arthritis; expects to begin its first clinical trial next year
Rockefeller University (New York, NY)	Studying the DNA of 3,200 inhabitants of Kosrae, a Micronesian island, to uncover the genetics of obesity
U.K. Biobank (Manchester, England)	Collecting blood, urine, and medical information from up to 500,000 British people; will begin next year and track subjects' health over the next 10-plus years to study the genetic and environmental factors of disease







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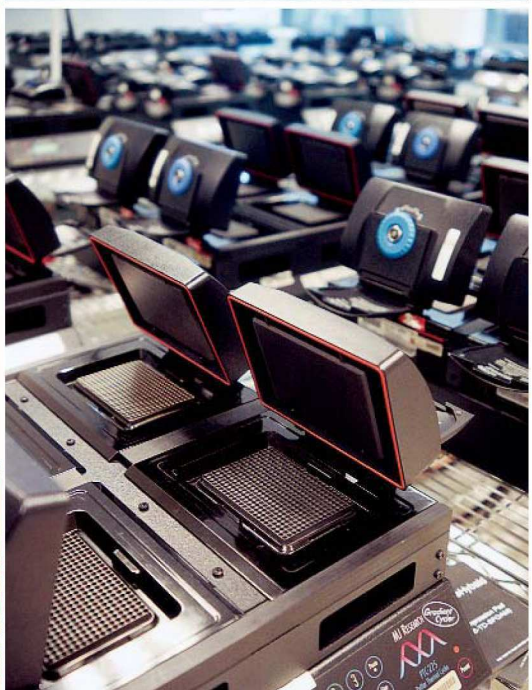


luck was on their side. During the 1980s and '90s, pharmaceutical companies had developed drugs to inhibit precisely this same protein, which they believed to be involved in asthma and other inflammatory diseases. DeCode decided to license a compound made by German drugmaker Bayer, says Mark Gurney, deCode's head of drug discovery. The drug had proved safe and had already made it to the last stage of human trials before Bayer shelved it because it wasn't much more effective than existing asthma drugs. Since deCode didn't have to make a new drug from scratch, it saved itself five to seven years of work, says Gurney.

What eight years ago started out as a **quirky gene-hunting startup** is starting to look a lot like **a real drug company.**

So far, the company's scientists have discovered 15 drug targets—proteins implicated in common diseases such as osteoporosis and schizophrenia. That's more "than any other individual research group," says James Weber, director of the Center for Medical Genetics at the nonprofit Marshfield Clinic Research Foundation in Marshfield, WI. "Most other labs in universities don't have the scale to crank the genes out like deCode."

Not only is the quantity of the drug targets they identify unusual, say deCode researchers, but so is their quality. Traditional methods of uncovering targets—studying lab animals or cells in petri dishes—often result in drug candidates that aren't very effective, says Gurney. "DeCode has unique assets that allow one to do more powerful and vastly more successful genetics studies of common, complex diseases," says Klaus Lindpaintner, head of the Roche Center for Medical Genomics. "This helps us feel more confident that the targets are more relevant to disease, and medicine derived against them will actually work."

The result: while traditional pharmaceutical companies will pursue half a dozen or more different targets in parallel for one disease, deCode places its bets on just one or two. That means less work, time, and money devoted to research on targets that turn out to be irrelevant, says Gurney.

That efficiency is starting to pay off. In addition to the heart-attack-drug clinical trials already under way, deCode plans to begin human trials of three more drugs by next year. Two of those trials will involve drugs that, like the heart attack drug, were originally developed by other companies for other uses. But early next year, deCode will begin human tests of its first drug made from scratch: a treatment for peripheral arterial disease, a narrowing of the arteries in the limbs. DeCode is also working on six other drug targets in partnership with Roche and Merck. All in all, what eight years ago started out as a quirky, off-the-beaten-path gene-hunting startup is starting to look a lot like a real drug company.

OUT OF ICELAND

In his spacious corner office on deCode's top floor, overlooking both the regional airport and one of Reykjavik's largest churches, Kari Stefansson is a little tired. He's just back, via an overnight flight, from a trip to New Jersey to talk with a pharmaceutical company. More and more these days, he's having to think about the real-world challenges that companies face in getting drugs on the market and ensuring they succeed there.

Before prescribing deCode's heart attack drug, for example, doctors will at least initially need to identify people with high-risk versions of the relevant gene. DeCode is in the early stages of developing a DNA-based diagnostic tool, but that approach is less than ideal, says Hákon Hákonarson, head of deCode's clinical programs. That's because multiple variants of the same gene and even nongenetic factors could all cause an elevation in heart attack risk. What's more, gene tests are more expensive and laborious than tests that measure "biomarkers" such as proteins in the blood. One of the goals of the heart-attack-drug trial, then, is to find a biomarker that is easily measured and accurately identifies all the people who have increased vascular inflammation that puts them at risk for a heart attack.

Indeed, treating people with specific genetic risk factors is just one of the ways Stefansson envisions doctors using deCode's drugs. "This is not black and white. This is not going to diminish the complexity of medicine; it's going to increase it," he says. In diseases like heart attack, numerous lifestyle and environmental factors closely intertwine with genetic factors. A patient with an average-risk variant of the gene, for example, might take the heart attack drug to compensate for diet or past medical history, Stefansson says, much as some patients with normal cholesterol levels now take cholesterol-lowering drugs to compensate for other risk factors. Proving the utility of such an approach will require still more human testing.

One of the biggest challenges deCode faces, however, lies beyond Iceland's shores. Many geneticists wonder if deCode's research findings in Icelanders, and the drugs developed based on those findings, will be relevant to other populations. Human geneticists have a long history of finding a gene for a particular common disease in one population, then failing to find links between that gene and the disease in another population. Nobody knows for sure why that is, but "it's critical," says Leena Peltonen, a medical-genetics professor at the University of Helsinki, Finland, and the University of California, Los Angeles. "If you think you've found a gene, you have to replicate the findings and prove it's applicable to other populations," she says.

It's an argument that vexes Stefansson to no end. What's important, he argues, is the ability to pinpoint the protein or pathway that has gone awry in a particular disease—and that's what deCode's gene hunting does. "You walk around here and you see that most people have two legs, two arms, and a head," he says. "It's outrageous to believe that the biological pathways involved in common diseases in Iceland are different than the biological pathways involved with the common diseases elsewhere." Nonetheless, deCode is working to show that the heart attack gene is correlated with disease in an American population and has already done so in a British population.

In the end, deCode is yet another biotech company working on yet another drug for heart disease. But it is also one of a handful testing a fundamentally new approach to drug development. If it pans out—and it could begin to in just a few years, with the availability of deCode's first drugs—millions of patients around the world could benefit from the genetic legacy of Benedikt Arnason and the thousands of other Icelandic volunteers. TR

Corie Lok is a *TR* associate editor.

Forging ahead: Kari Stefansson, deCode's founder and CEO, is venturing into new territory—drug discovery—and encountering critics along the way.

THE NEW FACE OF HOLLYWOOD

SONY PICTURES IMAGEWORKS IS LEADING THE WAY IN CREATING THE WORLD'S MOST REALISTIC DIGITAL HUMANS—PUSHING THE LIMITS OF WHAT'S POSSIBLE IN MOVIES, GAMES, AND COMPUTER INTERFACES.

BY GREGORY T. HUANG

Digital web design: A computer-generated Peter Parker clings to a speeding train in *Spider-Man 2*.

www.technologyreview.com

ATOP AN ELEVATED TRAIN BARRELING THROUGH DOWNTOWN, THE MASKED MAN IN THE RED AND BLUE SUIT IS IN TROUBLE.

Not only is he fighting a lunatic scientist who's trying to kill him with robotic tentacles, but he also needs to save the passengers on the train. It's all in a day's work for superhero Peter Parker, also known as Spider-Man—but it means months of work for an elite team of graphics gurus.

This action sequence from the megahit *Spider-Man 2* has dazzled millions of moviegoers this summer. Look closely at the villain, Doctor Octopus (played by actor Alfred Molina), and you'll see him grin maniacally and yell while ambulating along the top and sides of the train. Later in the scene, Spider-Man (Tobey Maguire) loses his mask as he braces himself against the front of the train, bringing it to a screeching halt. His frantic facial expressions appear convincingly natural.

With all the swift cross-cutting between images of superhero and villain, the audience probably does not suspect that the faces and figures appearing on the screen much of the time are not the real thing. Rather, they are digital concoctions created inside a computer at Sony Pictures Imageworks in Culver City, CA.

"We've reached a point where we can make every single thing computer-generated. Everything from the shattered glass in the train to all the buildings, tracks, and people," says Mark Sagar, a graphics supervisor on *Spider-Man 2* and Imageworks' resident expert on digital human faces. He points to the train sequence as it plays on his computer screen. "Watch what the camera does. Here it's going fast along the train, then underneath the performers, then in front of them, then a wide shot. How could you do that with a real camera?" But the digital faces on the people are the last, crucial piece of this puzzle. In the past, splicing footage of real actors into a digital scene required real cameras, difficult stunt work, and tweaking to get the look of the real and digital images to match; the ability to do computer-generated *everything*, including human faces, opens a wealth of creative possibilities.

Photorealistic digital faces—ones that can pass for real in still pictures or on the big screen—are among the last frontiers of computer graphics. Until recently, digital faces have looked fake when examined closely and have therefore been relegated to quick cuts and background shots. The problem is that we're extraordinarily sensitive to how human faces should look; it's much easier to fool people with a computer-generated *T. rex* than with a digital human. But advances in rendering skin, lighting digital scenes, and analyzing footage of real actors for reference are now allowing artists and programmers to control the texture and movement of every tiny patch of pixels in a computerized face. The Sony team hopes that audiences will be unable to tell the difference between Tobey Maguire and his digital double—perhaps the first time such verisimilitude has been achieved.

The stakes are huge. Digital effects are a billion-dollar business and growing fast; these days, a typical blockbuster film's budget can be $150 million, with half of that going to effects companies. Indeed, *Spider-Man 2* is just one example of Hollywood's increasing use of cutting-edge graphics research to create better digital actors, from stunt doubles of Neo and the multitude of Agent Smiths in the *Matrix* films to Gollum in the *Lord of the Rings* series. It's reached the point where the industry jokes about replacing actors with computers (the premise of the 2002 film *S1m0ne*). And Sony Pictures Imageworks, founded in 1992 and with more than 40 feature films to its credit, is in the vanguard of effects houses that vie for big studios' business *(see "Making Faces," p. 73).*

But the real benefit of digital actors isn't replacing live ones: it's delivering scenes that take viewers to places no real actor, or camera setup, could go. "It's giving directors more flexibility, and it allows them to do actions they can't do with real stunt people," says Scott Stokdyk, the visual-effects supervisor at Imageworks in charge of the *Spider-Man* series. "In the past, directors and editors have basically massaged the cut around different quick actions and camera angles to convey a story," Stokdyk says. "Now they don't have those kinds of limits." Thus liberated, directors can follow synthetic actors as they swoop around skyscrapers and dodge bullets in sweeping slow motion. What's more, actors can be digitally aged, or de-aged, without having to spend hours in makeup. Long-deceased movie stars could even be digitally resurrected.

And movies are just the beginning. Techniques for creating digital humans are pushing the broader frontier of computer graphics and interfaces. These efforts could enable strikingly realistic medical training simulations, lifelike avatars for e-mail and Internet chat rooms, and soon, much more compelling characters in games and interactive films. The technology, Sagar says, "is absolutely ready for prime time."

VIRTUAL VISAGE

Mark Sagar has always been torn between art and science. After college, he spent three years traveling the world, sketching portraits for a living. But the tug of technology made him return to graduate school in his native New Zealand to study engineering. "I never thought I'd spend years of my life studying the human face," he admits, sitting in his office at Imageworks, surrounded by books and papers on visual perception.

Hearing Sagar describe the human face as "a multichannel signaling device" suggests that the science and engineering side of him has won out. Understanding the science behind faces, he says, enables him to make a digital character's message come through more effectively on the screen. Expressions like downcast eyes, a furrowed brow, or a curled lip signify a person's emotional state and give clues to his or her intent.

Sagar's path to Hollywood opened almost by accident. In the mid-1990s, as a graduate student at the University of Auckland

PREVIOUS SPREAD: COURTESY OF SONY PICTURES IMAGEWORKS

Movies on his mind: Mark Sagar is resident expert on digital human faces at Sony Pictures Imageworks.

JOE TORENO

and as a postdoctoral fellow at MIT, he developed computer simulations of the human eye and face that could help doctors-in-training learn surgical techniques. His simulations looked so real that a team of dot-com entrepreneurs convinced him to cofound a graphics startup called LifeFX in Newton, MA. Its mission: commercialize software that everyone from filmmakers to Web businesses and e-mail providers could use to produce photorealistic likenesses of people.

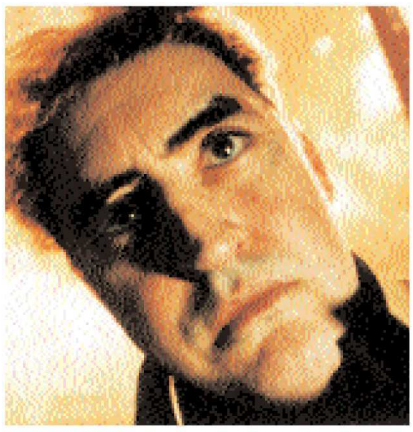
Sagar soon became a leading authority on digital faces for entertainment. In 1999, he came to Los Angeles to work on computer-generated face animations for films, including one of actor Jim Carrey. Paul Debevec, a graphics researcher who made his name creating virtual environments and advancing

DIGITAL ACTORS CAN NOW ZOOM AROUND SKYSCRAPERS, OVER TRAINS, AND UNDERWATER, EMOTING ALL THE WHILE.

digital lighting techniques, saw Sagar's films at a conference and was intrigued: he had never seen faux faces that looked so convincing up close. "That was the moment that made me cross the threshold of truly believing that a photoreal computer-graphics face would happen in the next five years," says Debevec, who is now at the Institute for Creative Technologies at the University of Southern California *(see "Hollywood's Master of Light," TR March 2004)*.

The two scientists struck up a collaboration, using Debevec's lighting techniques to render Sagar's digital faces—a combination that quickly catapulted them to the forefront of the field. It turns out that if you're trying to simulate a face, getting the lighting right is a big deal. Unlike previous computer simulations that looked odd in different contexts and had to be adjusted by trial and error, Sagar and Debevec's faces could be tailored to match the lighting in any scene. That's because they were built using a rich database of real faces photographed from different angles and illuminated by many different combinations of light. When LifeFX folded in 2002, Imageworks snatched up Sagar specifically for his expertise in faces.

He immediately began working on the first feature-film test of these techniques:



FACE VALUE
For this shot, Doc Ock's hair, eyes, skin, and subtly changing expression were rendered on a computer, using reference photos of actor Alfred Molina taken under various lighting conditions.

Spider-Man 2. The action scenes in the film required detailed and expressive simulations of the faces of well-known actors—a particularly tough problem, says Sagar. Not only are audiences quick to reject ersatz human faces in general, but they are particularly sensitive to faces they recognize; any discrepancy between digital and real could be perceived as fake. To make the simulations work, the researchers needed lots of reference footage of the real actors under different lighting conditions.

So Maguire and Molina each spent a day in Debevec's lab. Supervised by research programmer Tim Hawkins, they sat in a special apparatus called a "light stage" while four still cameras captured hundreds of images of their heads and faces making a variety of expressions and illuminated by strobes from every possible angle. The actors also had laser scans and plaster casts made of their heads and faces, so that high-resolution digital 3-D models of their likenesses could be built on computers.

JOE TORENO (FACE VALUE); COURTESY OF SONY PICTURES IMAGEWORKS (FACE-OFF)

Virtual face-off: Spider-Man and Doc Ock do battle in this all-digital shot made at Sony.

At Imageworks, Sagar and his team wrote user-friendly software so that dozens of artists could use the gigabytes of image data without getting bogged down in technical details. To make the train sequence look right, for example, Sagar's software combined images from Debevec's setup into composites that matched the real-world lighting on the movie set, then mapped the composites onto 3-D computer models of the actors. To make the faces move, animators manipulated the models frame by frame, using existing pictures and video of the actors as a rough guide. The software calculated lighting changes based on how the face models deformed—and illuminated the digital skin accordingly. The result: synthetic actors who look like Maguire and Molina (intercut with the flesh-and-blood ones) zoom through the air, around skyscrapers, over trains, and underwater, emoting all the while.

Imageworks is a prime example of how effects houses are integrating new research into their production pipelines more quickly than they did just a few years ago. (While audiences might be wowed by what has shown up at the multiplex lately, the fundamental graphics technology in films didn't change much in the 1990s.) "Before, there was a very long lag. Something would get developed, and then you'd wait ten years for a software company to commercialize it," says J. P. Lewis, an expert on graphics and animation at the University of Southern California's Computer Graphics and Immersive Technology lab. "Now, I think companies are much more aware of research, and they tend to jump on it much more quickly."

A walk through the darkened hallways of Imageworks this spring finds the team scrambling to put the finishing touches on the more than 800 effects shots for *Spider-Man 2*. It's a young, hip crowd sporting fashionable glasses and displaying mementos from the film on their desks—photos, action figures, a cast of Tobey Maguire's face. On the day he ships his last shot for the film,

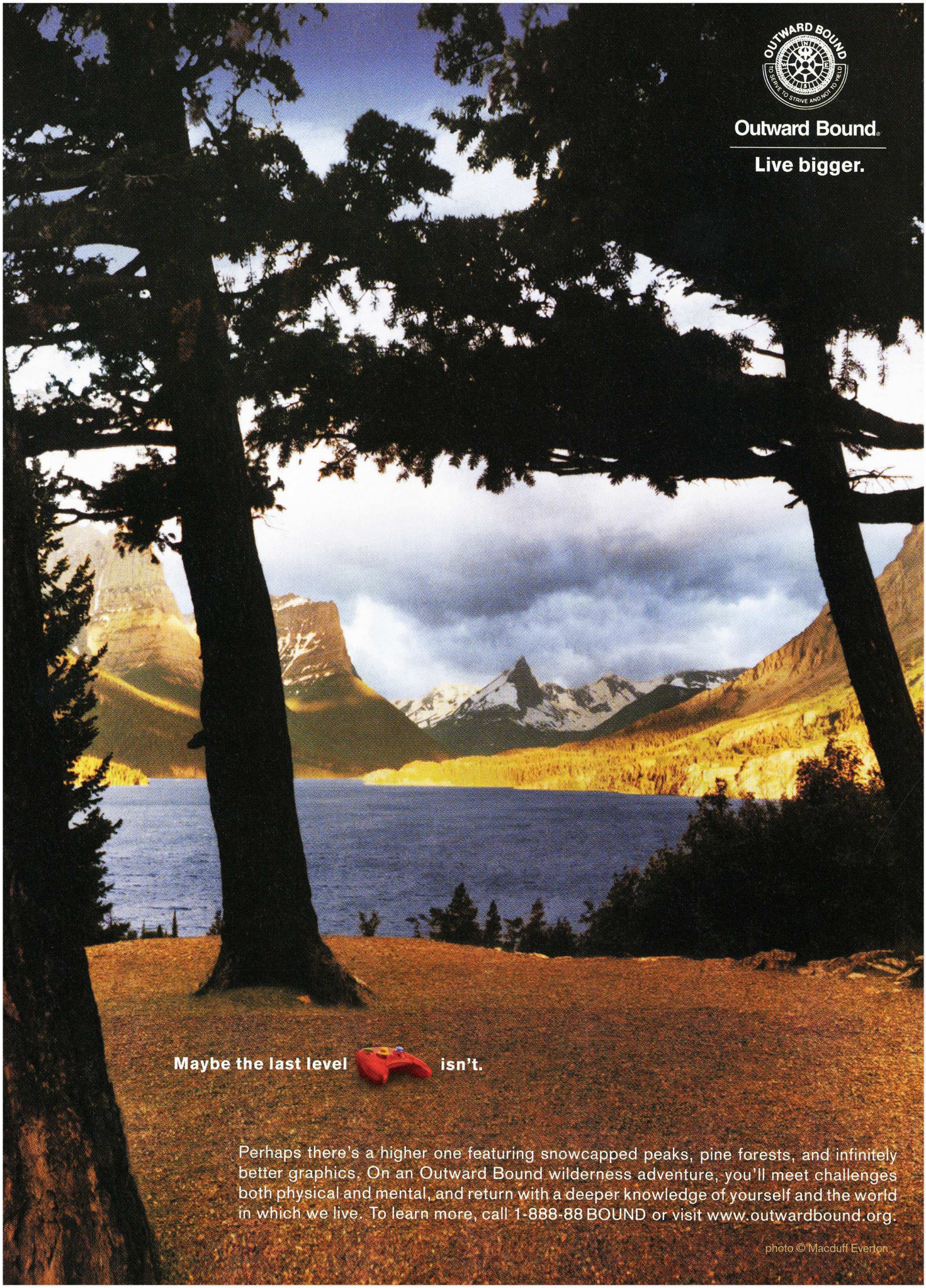

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photo © Macduff Everton

Knucklehead: A computer-generated face enables this close-up in *The Matrix Revolutions.*

visual-effects supervisor Stokdyk laments that there isn't more time. The biggest challenge, he says, was blending Molina's sometimes real, sometimes digital, face with his "Doc Ock" costume and comic-book-style surroundings. "To match reality," he sighs, "is almost impossible."

PUT YOUR GAME FACE ON

Indeed, despite the millions of dollars thrown at the problem, digital human faces still have a ways to go. What remains to be done may seem like incremental steps—making eye movements less robotic, capturing changes in blood flow so cheeks flush, getting skin to wrinkle just the right way during a smile—but they add up. "The last 20 percent could take 80 percent of our time to get right—but we're definitely in that last 20 percent," says Darin Grant, director of technology at Digital Domain in Venice, CA, which did character animations for this summer's *I, Robot.*

In the end, commercial audiences will decide the value of these digital doubles. "The ultimate test of what we do is how it looks on-screen and how it translates to production," says Grant. His colleague Brad Parker, a visual-effects supervisor and director at Digital Domain, maintains that digital humans will pay increasing dividends for filmmakers—and for the graphics community. "It's a big deal," he says. "It combines everything that's difficult about computer graphics."

Why it's such a hard problem—exactly what our eyes detect as "wrong" in a digital human—isn't yet well understood. But University of Southern California graphics researchers Lewis and Ulrich Neumann are trying to find out. In recent experiments, their group showed glimpses of real and digital faces to volunteers to see if they could tell the difference. The results were striking—and frustrating. "We spent a year working on these faces, but we couldn't fool people for a quarter of a second," Lewis says. He predicts that this work will lead to statistical models of how real

MAKING FACES

COMPANY	STANDOUT TECHNOLOGIES	BEST-KNOWN CHARACTERS	RECENT FILMS
Digital Domain (Venice, CA)	Large-scale scene animation; digital stunts	Animated Michael Jordan (TV commercial)	*I, Robot*, *The Day after Tomorrow*
ESC Entertainment (Alameda, CA)	High-resolution recording of emotive human faces for "playback" in computer-generated scenes	Neo, Agent Smith	*Matrix* series, *Catwoman*
Industrial Light and Magic (San Rafael, CA)	Skin rendering; digital characters and stunts	Yoda	*Star Wars* series, *Van Helsing*
Sony Pictures Imageworks (Culver City, CA)	Face rendering and animation using novel lighting and performance capture methods	Spider-Man	*Spider-Man* series, *The Polar Express*
WETA Digital (Wellington, New Zealand)	Rendering and animation of dramatic characters	Gollum	*Lord of the Rings* trilogy

COURTESY OF LUCASFILM LTD. (YODA)

human faces behave, which in turn will yield software tools that artists can use to make characters move their eyes just so or change expressions in other subtle ways that could be vital to believability.

Such advances should have a dramatic impact. Says Steve Sullivan, director of research and development at Industrial Light and Magic in San Rafael, CA, "We'll probably look back in 10 years and think today's digital doubles look horribly primitive."

And it won't only be movies that get a facelift. The same graphical simulation tools that filmmakers are starting to master will also help fuel the next big market for digital faces: video games. Today's games boast dazzling creatures and scenery, but their human characters are not even close to being photorealistic. It's just not practical to program in every viewing angle and expression that may arise during the course of a multilevel, interactive game.

That's where George Borshukov comes in. Borshukov, a computer scientist who designed state-of-the-art digital humans for the *Matrix* films (all those Smiths in *Reloaded* and *Revolutions* are his team's), is now applying face technology to games. A former technology supervisor at ESC Entertainment in Alameda, CA, Borshukov recently moved to videogame powerhouse Electronic Arts in Redwood City, CA. He says that next-generation gaming hardware will come close to demonstrating techniques for photorealistic faces in real time, but that trade-offs, approximations, and data compression will be needed to make it happen.

The problem is that with games, everything has to happen on the fly. Yet it still takes a few hours to render a single *frame* of today's best digital faces. That's workable if you have months to produce the scenes, as in a movie. In a game or interactive film, however, the particular image called for may not exist until the user orders it up with the flick of a joystick. Making this practical will require software that's thousands of times faster.

Five years down the road, experts say, a hybrid between a game and a movie could allow viewers/players to design and direct their own films and even put themselves into the action. You might first "cast" the film by scanning photos of real people—you and your friends, for instance—and running software that would create photoreal 3-D models of those people. Then, in real time, you could direct the film's action via a handheld controller or keyboard—anything from zooming the camera around the characters to making the lead actor run in a certain direction. Interactive entertainment, Borshukov says, "is where the real future is."

THE *MATRIX* MAESTRO

John Gaeta, the Academy Award–winning visual-effects supervisor on the *Matrix* trilogy, believes digital actors will make their biggest mark on interactive cinema and virtual reality.

Technology Review: Is the technology here for perfect digital doubles of movie stars?

John Gaeta: It is technically possible, but only with an enormous amount of finesse and effort. We're just scratching the surface of how to simulate all the nuance and detail of the human face as it emotes and speaks. For us, film is a guerrilla environment. You're given these assignments. You think as hard as you can, as fast as you can.

TR: Do digital actors signify a new era in filmmaking?

Gaeta: Yes, within limits. There will probably never be a need to do *Shakespeare in Love* with virtual actors. But in science fiction, psychological, or action genres, there are many interesting creative applications of a God's-eye camera view, such as providing heightened perception of an event that can't happen with standard cinematography. Having virtual actors and environments allows you to move the camera around in a limitless way.

TR: What's the future of digital actors in entertainment?

Gaeta: A new type of filmmaking is on the rise: interactive cinema. As a viewer, you'll be able to explore and participate in the world that surrounds the singular moment that's being presented to you. You'll be able to observe the action from any perspective you choose, and it will seem as photoreal as any movie you'll ever see; for that, we need virtual actors and virtual production design. In parallel, there will be immersive games and then full-blown simulations of real-world events and locations. People will interact in these worlds through avatars. The most evocative characters will be those based on the analysis and projection of emotions and identities of real people. That is without doubt the near- to mid-term future for virtual actors.

FACING THE FUTURE

Back at Imageworks, a storm of activity swirls around Mark Sagar. Artists are in crunch mode for another digital-actor project, this fall's *The Polar Express*, based on the popular children's book. But Sagar, who is not directly involved with that effort, is entranced by what's farther down the road—a more elegant approach to digital faces based on underlying scientific principles. "I see today's work as an interim stage where we still have to capture a lot of data," he says. "Eventually everything will use mathematical models of how things move and how they reflect light."

Sagar also sees much broader applications of digital humans in medical graphics, cooperative training simulations for rescue workers, and human-computer interfaces that could help users communicate more effectively with both machines and other people. Outside the entertainment industry, large organizations like Microsoft and Honda are pursuing research on advanced graphics and human modeling, including software that could allow you to create realistic virtual characters and digital avatars based on just a photo. Related algorithms could also help computers recognize faces and interpret expressions, either for security purposes or to predict a user's needs.

"We're at an interesting age when we're starting to be able to simulate humans down to the last detail," says Sagar. There's a certain irony in his statement. For once digital humans are done right, they'll be indistinguishable from the real thing; audiences won't even realize that artists and scientists like Sagar have changed the face of entertainment—and society. TR

Gregory T. Huang is a *TR* associate editor.

COURTESY OF JOHN GAETA

carver mead's

natural inspiration

The Silicon Valley legend has launched nearly two dozen startups and blazed a trail toward the future of electronics. The source of his ideas: the world around us.

BY SPENCER REISS PHOTOGRAPHS BY DEBRA MCCLINTON

Conventional wisdom descries a black hole between

the infinite uncertainty of modern theoretical physics and the can-do spirit of entrepreneurship and engineering. One more reason to ignore conventional wisdom, says Carver Mead, who became a technology legend by working both sides of what often seems an uncrossable divide. A Caltech stalwart—he is the emeritus Gordon and Betty Moore Professor of Engineering and Applied Science—Mead is one of the seminal figures in the story of Silicon Valley, with a résumé stretching back to integrated-circuit pioneer Fairchild Semiconductor and more than 20 startups to his credit.

Mead's early work in "electron tunneling" provided insights crucial to the development of solid-state electronics. His calculation of the theoretical potential for shrinking transistors gave Intel founder Moore the basis for his eponymous law, which predicts the steadily increasing power of microchips. And in the early 1980s, Mead and Caltech colleague Richard Feynman, the late Nobel laureate physicist, took circuitry into a new dimension by exploring "neuromorphic" electronics modeled on living organisms. Along the way Mead has stacked up prizes, including the $500,000 Lemelson-MIT Prize for invention and innovation and the National Medal of Technology in 2003. But his proudest achievement is a string of companies that includes touch pad maker Synaptics and the revolutionary image-sensor and camera startup Foveon, both outgrowths of his work in neuromorphic computing.

Spencer Reiss talked with Mead, who turned 70 this year, at his house among the redwoods in Woodside, CA.

TECHNOLOGY REVIEW: You're famous for saying, "Listen to the technology."

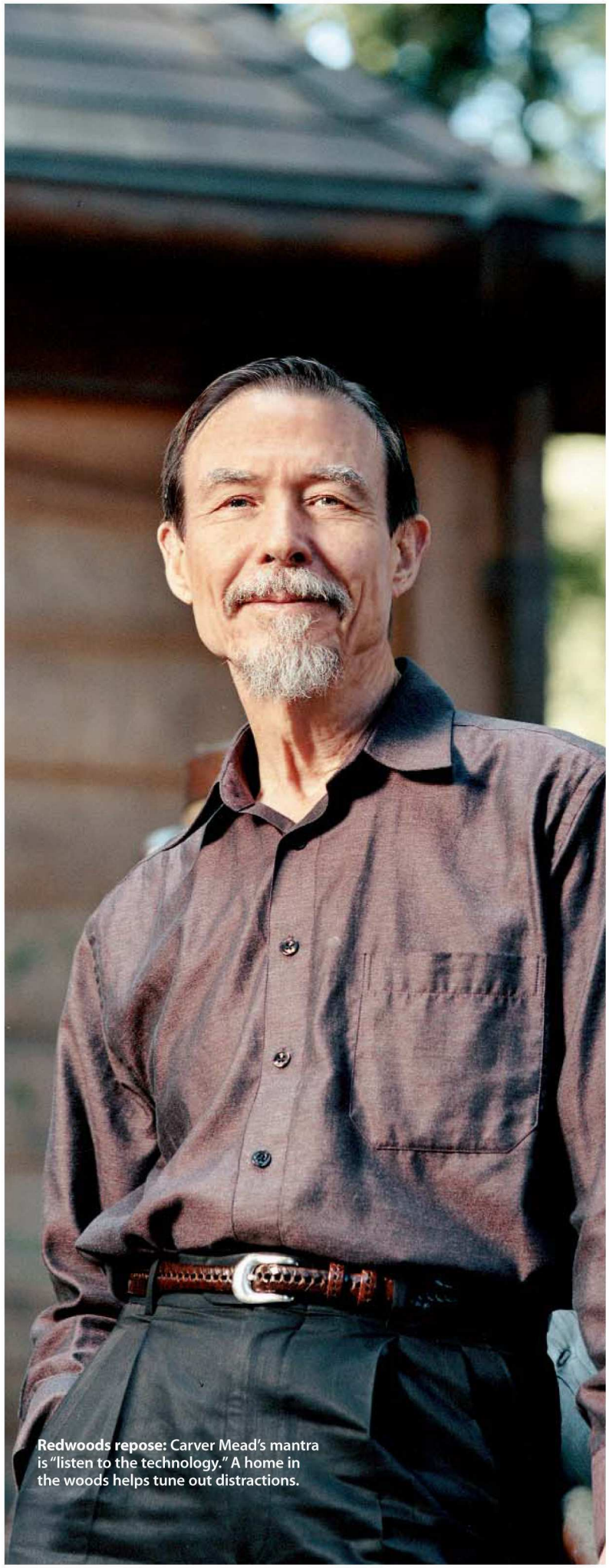
CARVER MEAD: To understand reality, you have to understand how things work. If you do that, you can start to do engineering with it, build things. And if you can't, whatever you're doing probably isn't good science. To me, engineering and science aren't separate endeavors. It's like, "Are you a husband or a father?"

TR: How do you decide what to pursue?

MEAD: Are you kidding? Research is a matter of love. It's not a left-brain thing. Once you figure out something, *then* you construct an elaborate rationale—the talks you eventually give that make it all sound so simple. Until then, I get angry when people ask me what I'm working on, because I have no way yet to express it.

TR: Is that what venture capitalists are for—to be cold-blooded about what to put resources into?

MEAD: All my favorite VC types—I know that sounds like an oxymoron, but actually I do like some of those guys—say the same thing: they go with their gut. Does the technology have enough potential applications to score at least one? Spreadsheets won't answer that.



Redwoods repose: Carver Mead's mantra is "listen to the technology." A home in the woods helps tune out distractions.

TR: What about looking at the marketplace?
MEAD: Sure, you can analyze the marketplace, talk to customers, do all the things they teach you in business school. The problem with "demand pull" is that by the time you have a real product, the market will have moved on. You're doomed to playing catch-up. I prefer "technology push"—find an interesting new technology and try to come up with uses for it. "A solution looking for a problem" is supposed to be a terrible epithet, but in my experience it works.

TR: For example?
MEAD: Impinj, a company started by a former student of mine at Caltech, Chris Diorio. I'm on the board. Starting out with something completely unrelated—neurally inspired computing—he came up with a very precise and low-power way to put a charge on a floating-gate transistor, which is the basis for flash memory. It was a classic "solution looking for a problem," which is turning out to be RFID, the little [radio frequency] identity tags to put on things. They're the ultimate lower-power device—picowatts, whatever you can get out of a little antenna. So instead of just having a "dumb" tag that can tell you its name and nothing more, you get a smart one that updates itself as it goes. You get a package or a product that can tell you its whole history, right there.

TR: Peter Drucker says, don't solve problems, seize opportunities.
MEAD: Right. If Impinj had looked around and said, "Hey, let's do RFID," they would have ended up with a nonrewritable tag. Just like a dozen other companies out there now.

TR: RFID tags for Wal-Mart are a long way from trying to reverse-engineer computers from biological models...
MEAD: When you've finally got a product, the fact that you were inspired to go that way by thinking about touch and vision and hearing or whatever doesn't matter much. You're on to making products, and everything that led up to that falls away.

TR: That's a little sad, no?
MEAD: Of course it is, but it's what happens when you start a company. The unlimited potential of your new technology—it's a

Mead's Startup Menu

Carver Mead has helped found more than 20 technology companies. A selection of his newer ventures:

ACTEL Mountain View, CA
» **Field-programmable gate array chips used in telecommunications**

FOVEON Santa Clara, CA
» **Multilayer silicon sensors for photographic imaging**

IMPINJ Seattle, WA
» **Low-power "self-adaptive" microchips**

SONIC INNOVATIONS Salt Lake City, UT
» **Advanced digital signal processing for hearing aids**

SYNAPTICS San Jose, CA
» **Touch pads and software for portable electronic devices**

huge high just thinking about it. But once it's manifest, once it becomes a product, it's not a myriad of anything; it's one thing. So inevitably, there is a huge postpartum—a sense of all the things you weren't able to do.

TR: Is that when you pull up stakes?
MEAD: It's happened with every company I've worked with. They get to the point where they're successful, they're on a track, and there's less and less that someone like me can contribute. You actually become a distraction: they're trying to focus, and you're wandering around thinking about all these interesting new questions. That's when it's time to leave.

TR: Some people think young technologists need to spend more time learning how to market their ideas.
MEAD: Science is not just about self-expression; you have to be able to explain what you're doing. Dick Feynman was one of the best marketers I have ever met. He never wanted to admit it—in his day, anything entrepreneurial was socially unacceptable for an academic—but he was able to position physics as something exciting, in a way that has survived to this day.

TR: You and Feynman were behind a big neuromorphic-computing project launched at Caltech in the '80s. What happened?
MEAD: Part of the problem was the refusal of the CS [computer science] community to have a new thought—the fact that there might be inherently more powerful ways to do computing. People said, "Everything's a Turing machine, and that's that." No matter that we already have a working example of a massively parallel machine—the animal brain. And meanwhile, now, the quantum computing guys have come along and showed yet another alternative model—one that in theory will solve problems that are exponentially unsolvable by a Turing machine. I'm making no statement about the realization of quantum computers—we still don't know about that. I'm just talking about our understanding of computing in the abstract. You need a fundamentally new conception of that if you want to try to make a better machine.

TR: Another neurally inspired company you've been involved with makes advanced hearing aids, Sonic Innovations.
MEAD: The thought process there came from thinking about how human hearing works, but again the actual device is just a little digital signal processor. The same thing happened with the idea of neural networks, by the way. They became just another algorithm for existing computers.

TR: What about Foveon, the camera company you founded in 1997? Most people probably don't realize that its roots are in studies of the eye.
MEAD: We started out making models of the retina, which by itself might make a big difference to a few people, but it's not enough of a commercial opportunity to justify big investment. What we realized was that if you took what we were doing and strip out the retina part, that's a really good image sensor—so let's do that. Foveon technology captures light directly, consuming less power and requiring far less processing than the file captured by a conventional digital camera. But when we explain it today, we don't have any reference to anything neural.

TR: So we're still at square one with neuromorphic computing?
MEAD: Actually, quite a lot of progress has been made. One of the exciting things that grew out of neuromorphic thinking is Lloyd Watts's company Audience. They've got a working cochlear model that builds a significant portion of the auditory pathway—including precision signal recovery and sophisticated analysis—into a chip-level component. It's more than just a better microphone; think of it as the auditory front end for any device that wants to use sound as an input.

TR: Voice recognition lives!
MEAD: Voice recognition as we know it is really brain dead. I shouldn't say brain dead—a lot of smart people have worked on it for many years. But it's an old paradigm. It's advancing logarithmically with processing power; that's about it. And yet we have these incredible working models right here—our own eyes and ears. That's where we want to be looking.

TR: Hearing, vision—the same problems you picked out nearly 20 years ago are still interesting problems.
MEAD: They're even more interesting, because we're starting to know enough about them to make some progress. It's taken this long to get the engineering-oriented people talking to the physiology people. Lawyers talk about "Chinese walls" in organizations; well, the barriers between scientific disciplines have been fierce.

TR: Is it the inherent difficulty of adapting digital technologies to our mostly analog human world?
MEAD: Digital abstraction is a wonderful thing. It substitutes a very simple set of logic operations—"and," "or," and "not"—for an infinite set of physical things. Working in analog is much harder, because there are essentially countless ways for the thing to go wrong. You're working with the physics itself, rather than with some very small set of circuits that have been crafted to show digital behavior.

TR: We can't let you get away without asking about Moore's Law. You get a lot of credit for its formulation.
MEAD: Gordon had observed what was happening and asked me how far things could go, how small you could make the transistors. We did some work in the lab, and the answer turned out to be .15 microns [150 nanometers], maybe smaller. That was shocking at the time, but it turns out to have been conservative.

TR: So how far can it go?
MEAD: I looked at things again a few years ago, and if you don't do anything differently, you can get down to 30 nanometers—a factor of five from what we originally said was going to be easy, and still a long ways from where things are today. So it's certainly not going to stop.

And at the same time, we don't have to keep doing things exactly the way we are doing them today. I for one certainly hope we don't. TR

Salisbury, CT-based writer Spencer Reiss likes to interview people smarter than he is. The last time he did it for *TR* was with venture capitalist Michael Moritz, the man behind Google (April 2004).

THERE'S NOT ENOUGH ART IN OUR SCHOOLS.

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It's a long way from the Apollo Theatre to the Apollo program. And while his playing may have been "as lofty as a moon flight," as *Time* magazine once suggested, that would be as close as Louis Daniel Armstrong would ever get to taking "one small step for man."

Instead of a giant leap, Louis Armstrong delivered one giant free-form crazy jazz groove for mankind.

But as the jazz musician of the 20th century, giant leaps were simply a matter of course for Satchmo. For no one has ever embodied the art form the way he did. It was he who helped make virtuoso solos a part of the vocabulary. It was he who was honored with the title "American goodwill ambassador" by the State Department. It was he who was the last jazz musician to hit #1 on the Billboard pop chart.

Armstrong left his footprints on the jazz world, wearing lace-up oxfords.

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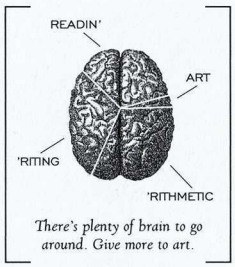

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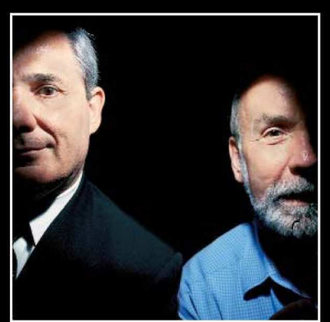
DEMO

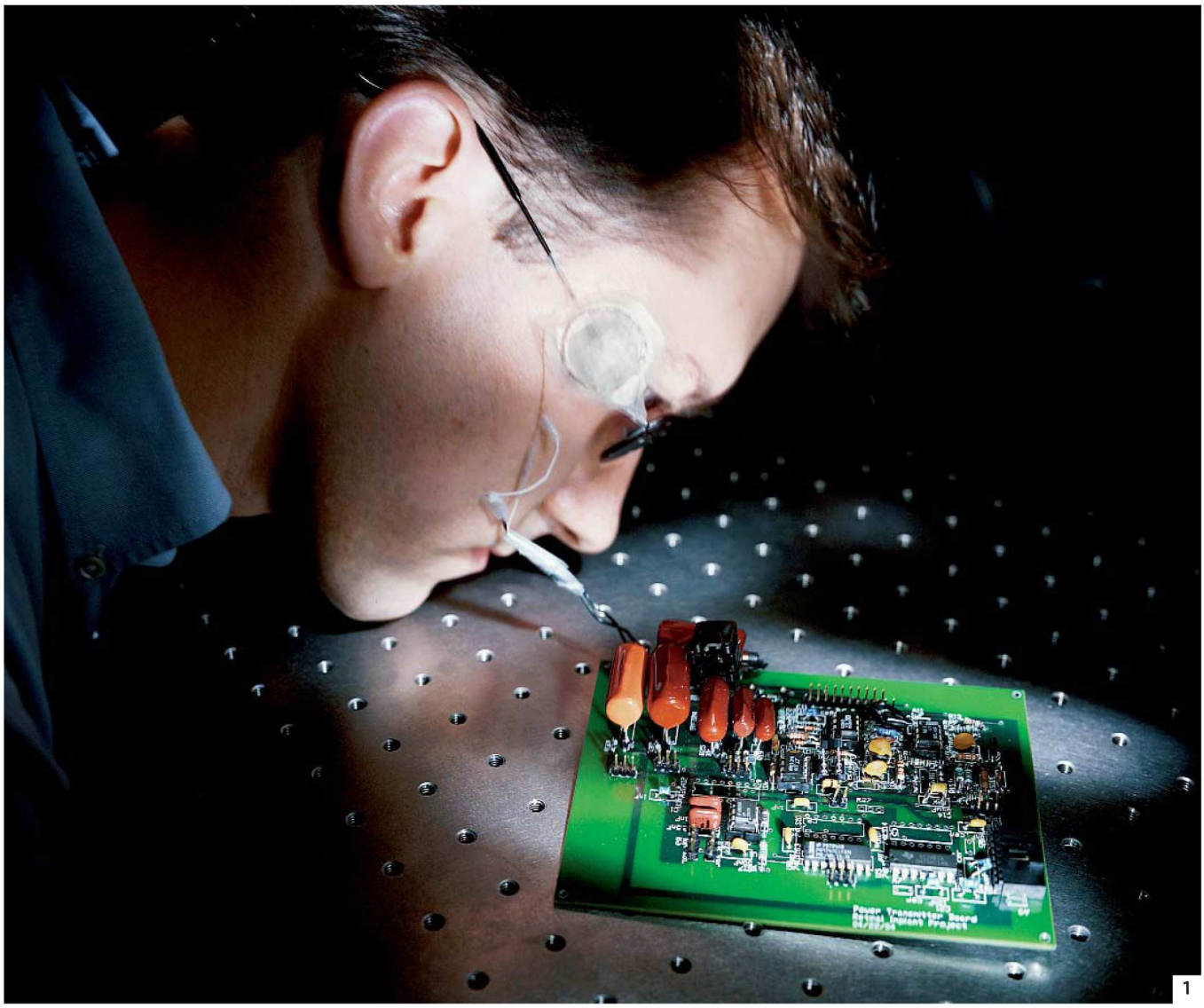
ARTIFICIAL RETINA

Blindness has defied doctors' search for a cure for decades. Joseph Rizzo and John Wyatt have developed an electrical implant that could finally help millions of people see again.

IN THE MID-1980s, neuroophthalmologist Joseph Rizzo III was researching retinal transplants to restore blind people's vision. One day, removing a lab animal's retina, a tissue-thin membrane that lines the back of the eyeball's interior, he had an epiphany. "The moment I made the cut, I said to myself, 'What in the hell are you doing?'" Rizzo recounts. He realized he was cutting nerve connections that are actually spared in many forms of blindness. The retina's light-sensing cells die off in retinitis pigmentosa and age-related macular degeneration, which affect millions worldwide; but the nearby neurons that ferry the signals from those cells to the brain remain intact. So Rizzo conceived of a retinal prosthesis—an implant that would take a wireless signal from a video camera, bypass the light receptors, and stimulate the healthy nerve cells directly to feed the image to the brain. Rizzo, working at the Massachusetts Eye and Ear Infirmary and the Boston VA Medical Center, teamed up with MIT electrical engineer John Wyatt Jr. to pursue the scheme. In 1988, they launched the Boston Retinal Implant Project, which today comprises 27 researchers at eight institutions. The team has already done short-term human tests and hopes to test a permanent prosthesis by 2006. Wyatt and Rizzo recently gave *TR* contributing editor Erika Jonietz a peek at their progress.



Pushing back the darkness: Joseph Rizzo (left) and John Wyatt's retinal implant (opposite page) sits on top of the eyeball and uses a tiny electrode array to stimulate sight-generating neurons.



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1. IMAGE RELAY. In a small, windowless workroom jammed with tables and equipment in his MIT lab, Wyatt explains how a real-time image is captured and relayed to the retinal prosthesis. While he talks, a visiting scientist named Shawn Kelly models the system's external parts. The idea: a small, commercial digital video camera (the researchers haven't chosen one yet) would be mounted on a pair of glasses. As the user "looked" about, a transmitter—now just a coil of wires, attached to a circuit board that will be packaged and worn on a belt—would send images wirelessly from the camera to the implant in his or her eye. "Here's the transmitter coil," Wyatt says, pointing out two concentric copper rings taped to the earpiece of the glasses. Using radio waves, he says, the inner ring sends the data to the prosthesis, while the outer coil sends it power.

2. MESSAGE RECEIVED. Placing the glasses next to a model of an eyeball, Wyatt shows how the transmitter coil lines up with a similar receiver coil on the implant, which sits on the surface of the eye. "In our design, we put almost all of the mass of the implant outside the eyeball," Wyatt says. "For years, we wanted to put everything inside. But the eye doesn't like stuff inside; that's why it doesn't have a zipper." Between 1998 and 2000, the team did a series of experiments with an internal implant, placing electrodes inside the eyes of blind volunteers for a matter of hours and firing the electrodes in different test patterns. "People saw spots and occasionally lines, but they didn't see quite as much as we had hoped," Wyatt says. "We think that people might see better if they have more time to spend with the implant and really learn how to use it." So the team worked on developing a prosthesis better suited to permanent use. The current outside-the-eyeball design is the result. The implant is attached to the eye's surface with small sutures to keep it from shifting as the eye moves normally in its socket. The only thing that penetrates the eye is a little electrode array 10 micrometers thick, two millimeters wide, and three millimeters long. The array slips underneath the retina, where the electrodes stimulate surviving nerve cells in response to images from the camera, providing a small patch of vision.

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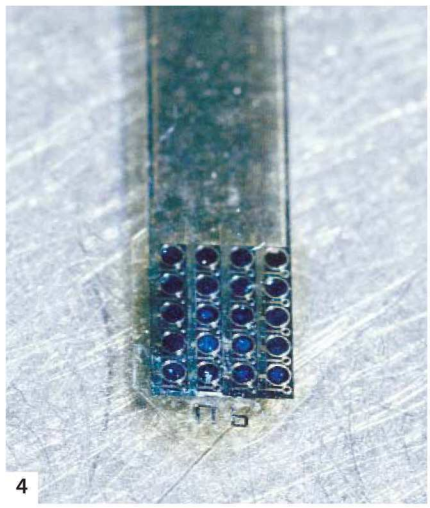
3. SYNTHETIC VISION. Wyatt pulls the implant off the model and sets it down atop a nearby circuit board to get a better look. A flexible, whitish polymer that molds to the eye forms its base. The electronics sit on the pentagon at the top. Wyatt points to a small black square in that region that acts as the implant's brain. This chip, designed in his lab, receives image data and power from the transmitter and figures out the pattern of electrode firings that will best recreate the image from the camera. At the bottom of a thin connecting piece of polymer are the receiver coil and, to its left, on a clear, flexible strip, the electrode array itself.

4. GETTING CLOSER. Rizzo moves the implant under a magnifier to examine the array. It currently consists of only 15 electrodes, each 400 micrometers across. "An electrode will drive a cluster of nerve cells nearby," says Rizzo. Although this will provide only a small area of low-resolution vision, Rizzo thinks it will help with his first goal: improving blind people's quality of life by allowing them to walk around unfamiliar areas more easily than they can with canes—"and a cane's pretty good," he says. After 16 years of research, Rizzo and Wyatt know achieving even that limited goal will be a giant step forward in artificial vision.



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Ant Power Packs

BY ERIKA JONIETZ

Cell phones used to be just phones, but now they're organizers, Web browsers, cameras, and music players, too. As the power-hungry functions pile up, running phones on batteries gets trickier. Cell-phone makers have been hoping micro fuel cells—tiny versions of the devices touted as a source of clean power for cars—would be the answer. But problems with size and power have stalled early methanol-based versions in academic and industry labs. So Renew Power, a spinoff of the University of Illinois at Urbana-Champaign, is turning to formic acid, the chemical sprayed by black ants on the attack.

This spring, company engineers began making calls on a Nokia phone using their fuel cell. "We're the first to demonstrate that we can power a cell phone with a fuel cell that actually fits in the phone," says Richard Masel, Renew cofounder and chief technology officer.

It took a bit of international maneuvering to get to this point. In 2003, former executives of Canadian fuel cell developer Ballard Power Systems helped found Tekion in Vancouver, British Columbia, to license and develop fuel cell technologies. A search for promising new approaches to powering cell phones and other portable electronics led Tekion to the formic-acid fuel cells Masel was developing at the University of Illinois. But the research had been funded by the U.S. Defense Advanced Research Projects Agency, "so there was no way it was coming to Vancouver," says Tekion cofounder and CEO Neil Huff. So Tekion's founders and Masel formed Renew Power as a U.S. subsidiary of the firm. (Huff serves as CEO of Renew as well.) Tekion and IllinoisVentures, a state venture capital fund, have funneled $1.8 million into Renew, and Huff hopes to begin pilot production of fuel cells for mobile handsets by early 2006.

Of all the markets for micro fuel cells, "handsets are the big prize," says Atakan Ozbek, vice president for energy research at technology research firm ABI Research in Oyster Bay, NY. "The potential is huge." Nearly 500 million handsets were sold last year, and this year predicted sales are even higher. But companies hoping to capture that prize face huge challenges. For instance, Ozbek says, when a cell phone "is on standby, it's drawing almost no power. But once you get a voice call, it increases." This dynamic change in power requirements is not something fuel cells typically handle well, he says.

RENEW POWER

HEADQUARTERS: Champaign, IL

UNIVERSITY: University of Illinois at Urbana-Champaign

INVESTMENT RAISED: $1.8 million

LEAD INVESTORS: IllinoisVentures, Tekion

KEY FOUNDERS: Neil Huff, Malcolm Man, Richard Masel, David McLeod, John Sutherland

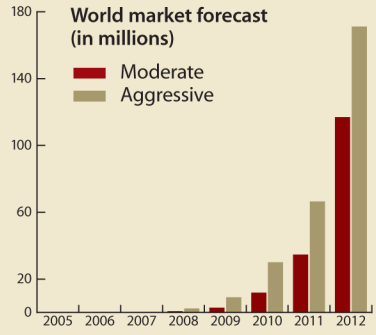
Only three years ago, industry watchers expected companies such as Samsung to sell methanol-powered cell phones by 2003. But problems with dynamic power demands, and with operating temperature and size, have stymied their development, and none has made it from lab to store.

Using formic acid as the fuel can solve all these problems, Masel says. For starters, although formic acid yields less electricity per molecule than methanol, it can deliver energy more rapidly than a comparable methanol fuel cell, getting around the dynamic-power issue. Formic-acid fuel cells also operate just fine at room temperature; to achieve the same level of power, methanol fuel cells must work at a scalding 60 °C and up—impractical for a device used near the face. And methanol must be used in a diluted form in fuel cells; handling it requires tiny pumps and pipes that increase the devices' size. Formic acid doesn't face that problem, so Renew's fuel cells require no moving parts—just a replaceable fuel cartridge.

A single cartridge should power a cell phone at least twice as long as the typical lithium-ion battery used today, Huff says. Some experts, however, are skeptical that formic acid will beat methanol into portable electronics. Two of the fuel's biggest problems are availability and toxicity, says Paul Kohl, director of the Georgia Tech Center for Innovative Fuel Cell and Battery Technologies. "Methanol is a more plentiful fuel than formic acid. You can buy it on the drugstore shelf," he says. "And I can wash my hands in methanol; I can't in formic acid," because the concentrated acid would burn his skin.

Predictably, Renew Power says it is well on its way to solving such problems. The real competition, Huff believes, is powerful, established lithium-ion batteries. But as cell phones grow more complex, the need for more power in a small space should eventually push the industry toward fuel cells. Being the first to have a fuel cell that fits inside a phone could put Renew Power at the head of the pack. TR

MICRO FUEL CELL SHIPMENTS



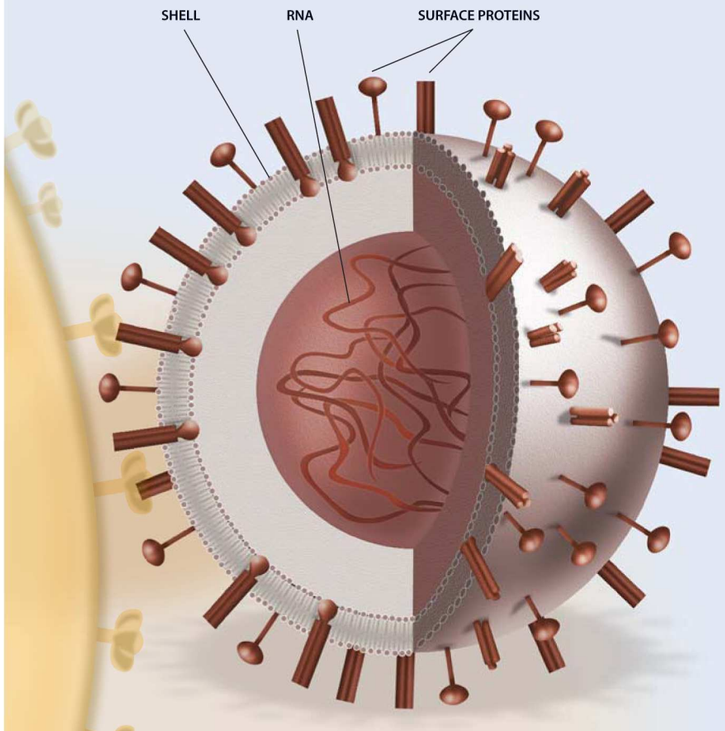
SOURCE: ABI RESEARCH (SHIPMENTS)

OTHERS IN MICRO FUEL CELLS

COMPANY	TECHNOLOGY/APPLICATION
Medis Technologies (New York, NY)	Sodium borohydride fuel cell/ portable electronics
Motorola (Schaumburg, IL)	Methanol-reforming fuel cell/ two-way radios
MTI MicroFuel Cells (Albany, NY)	Direct methanol fuel cell/ portable electronics
PolyFuel (Mountain View, CA)	Direct methanol fuel cell/cell phones, laptops

Flu Vaccine Production

FLU VACCINES SAVE LIVES, but in any given year, supplies can fall short. The current method of producing the vaccine takes up to six months, forcing health officials and vaccine manufacturers to guess how many doses will be needed and which flu strains will hit hardest well ahead of flu season. Guessing wrong on either count leaves people unprotected come fall. A technique called "reverse genetics" could make production fast and flexible. Here's how it compares to today's flu-vaccine manufacturing method. **TEXT AND ART BY 5W INFOGRAPHIC**



INFLUENZA VIRUS

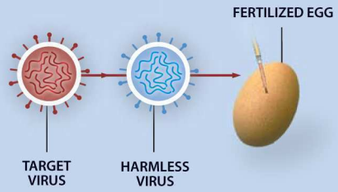
A flu virus is a shell containing eight strands of genetic material known as RNA. One of the strands encodes a protein on the virus's surface that allows it to infect cells, such as those in the throat and lungs. Once inside a host cell, the virus hijacks the cell's molecular machinery to replicate itself many times. Another RNA strand encodes a protein on the virus's surface that helps it burst out of the host cell, which it kills in the process. Once out, the replicated viruses seek out new cells to invade, spreading infection.

MAKING THE VACCINE

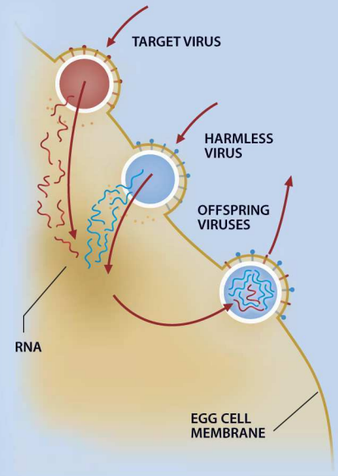
Each year, World Health Organization (WHO) researchers make three "seed" flu strains based on predictions about which viruses will predominate in the fall. Each seed strain has surface proteins from a target virus, but most of its genetic material is from a harmless flu virus.

Current Method

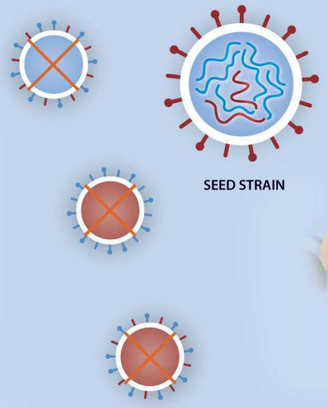
1 Each seed strain is made by injecting a target strain and a harmless strain together into a fertilized chicken egg.



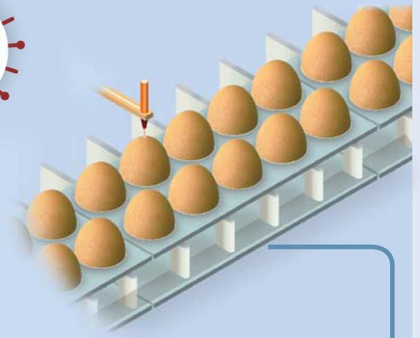
2 As the two viruses replicate inside the egg, their RNA strands mix. The result: offspring viruses that contain genetic material from both.



3 Scientists sift through the offspring viruses to locate ones that have the right combination of RNA strands from the target and harmless viruses. Finding them is the most time-consuming part of the process and can take months.

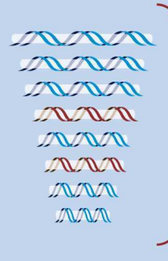


4 WHO then gives the seed strain to vaccine manufacturers, who inject it into fertilized eggs, where it multiplies. Manufacturers use approximately 90 million eggs for each strain—too many to order quickly when the breakout of a new strain takes health officials by surprise.

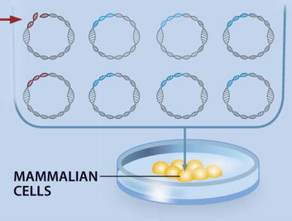


Reverse Genetics

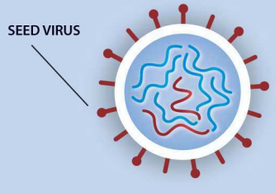
1 WHO scientists make DNA versions of the RNA strands they want to end up in the seed strain.



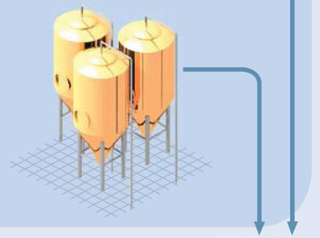
2 They splice these DNA copies into circular pieces of DNA called plasmids, which are inserted into mammalian cells growing in petri dishes. The plasmids keep the seed strain's genetic material from getting lost in the cells.



3 Genes in the plasmids instruct the cell to make new viruses, complete with the desired combination of RNA strands and surface proteins.

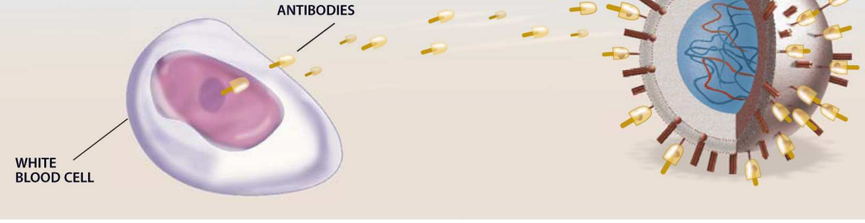


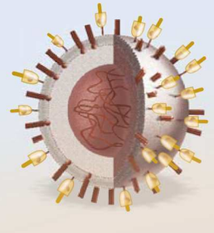
4 WHO researchers give the seed strain to vaccine manufacturers, who add it to millions of mammalian cells growing in large fermenters. The seed strain infects the cells and multiplies.



THE VACCINE IN ACTION

1 When a person gets vaccinated, the seed-strain viruses compel white blood cells to begin a trial-and-error process of manufacturing proteins called antibodies, which bind to the virus's surface proteins.





2 When a sneeze or a handshake exposes the person to one of the target viruses, the immune system immediately produces the correct antibodies, which cap the proteins on the target virus's surface, blocking its ability to infect cells.

THE VACCINE

In both methods, the manufacturers mass-produce the three strains separately and then inactivate them with chemicals to prevent them from replicating in people. It takes about fifteen-millionths of a gram of each of the three strains to make one dose of vaccine.

IM, I Said

IF YOU AREN'T USING INSTANT MESSAGING, IT'S TIME to start. ▪ IM, as it is universally known, is a very different beast than other forms of electronic communications. IM is immediate, like a phone call, but it's also text, like e-mail. Also like e-mail, IM is amenable to multitasking. Unlike a telephone call, though, IM lets you politely interleave messages with other work, typing a few lines to a friend and then writing another paragraph on that annual report. You can even carry out multiple IM conversations at the same time, each in its own window. IM is a mixed blessing, but it's a tool that you're better off harnessing than ignoring.

People who don't use IM tend to dismiss it as the territory of gabby teenage girls. But grownups are flocking to this medium, too. A study this February by the Pew Internet and American Life Project found that 21 percent of IM users use it at work. This is not surprising: IM is dramatically more effective than e-mail for short, time-sensitive messages.

To use IM, you'll need an account with one of the IM providers—America Online is the most popular, followed by Yahoo! and MSN—and a piece of client software. AOL will try to get you to download its AIM software, but resist the temptation. The AOL program displays not only stock and news tickers but also advertisements—including occasional 15- or 30-second video segments, complete with sound that comes unbidden from your computer's speakers. Ick! You're better off with iChat on the Macintosh or the open-source Gaim—the GNU IM software for Windows and Linux machines. Businesses that care about the security of their messages can either set up their own IM servers or configure their IM users' software to use encryption.

Once you let IM into your life, you'll wonder how you did without it. I use IM to plan dinner with my wife, answer questions from students, and give my seven-year-old daughter a reason to learn how to type. It's great for messages that matter *now* but will be obsolete by the end of the day—or even after a few hours. I frequently IM my editor to check the status of my various projects; it's the most effective way I know to get a quick answer out of a busy person.

Smart companies want to control instant messaging but not destroy it, because IM is tremendously useful.

Last spring, I found instant messaging particularly helpful in a class I was teaching. My students could check to see if I was online and, if so, just pop me a question. Some students would send me e-mail instead, but the perpetual clutter in my in-box meant that those students typically had to wait hours or even a day before they got an answer. By then, of course, the students had usually answered their questions through other channels—typically by IMing their friends.

IM can also be a huge time waster. Put a few dozen people on your "buddy list," and you'll always have someone who wants to chat—even when you'd rather not. AOL's software alerts you when your buddies log in and log out. Although it's tempting to drop friends a greeting whenever they appear, being on the receiving end of such attention gets annoying. If you don't learn restraint, you might find yourself blocked—that is, your IMs will be automatically rejected by friends who are tired of hearing from you. Of course, if your IM buddies shut you down, you can always cruise websites like craigslist, which are filled with "I'm bored; please IM me!" messages from alleged 20-somethings.

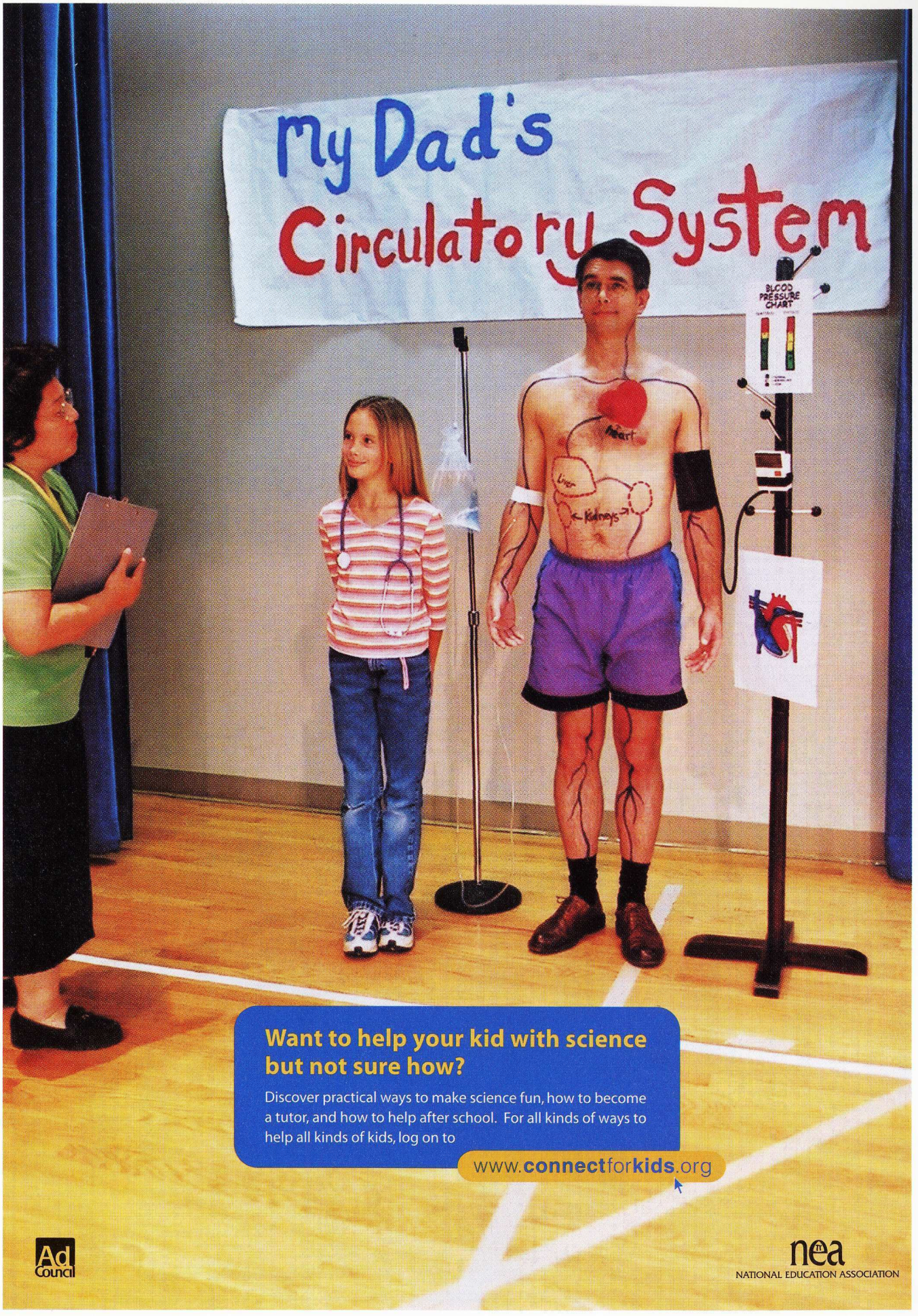
Not surprisingly, this kind of unrestricted IM scares many parents—especially parents of 15-year-old girls eager to pass themselves off on Internet dating sites as 18. Some parents buy programs like ChatBlocker that promise to either block or record all of your IM chats on a particular computer. These programs can give you a false sense of security, though: your teenager can always chat using a friend's computer or a public Internet machine, or even a cell phone.

Parents aren't the only ones looking to control IM. FaceTime Communications markets a program for businesses, called IM Auditor, that will record IM between employees, limit who can IM whom, and automatically interrupt chats that stray into unacceptable subject areas. (The product's ostensible purpose is to help companies comply with federal regulations that define what information can be communicated over the Internet and what needs to be preserved for auditors.)

Smart companies want to control instant messaging but not destroy it, because IM is tremendously useful. For example, you can arrange for several people to participate in the same conversation, saving a lot of message relaying that undermines clear communications. My wife participates in an online writer's group; its members get together at a predetermined time once a month in a chat room and discuss each other's work. Trying to do this by e-mail, with its lack of immediate give-and-take, would produce very different results—or none at all.

That's why many educators say that it's better to teach your kids about the potential dangers of hooking up with strangers than to try to use technical means to restrict their communications in the first place. You might even teach them some good time management and IM etiquette while you're at it. In a future increasingly filled with instant-messaging opportunities, that's a skill that they—and you—will find vital.

Simson Garfinkel is an incurable gadgeteer, an entrepreneur, and the author of 12 books on information technology and its impact.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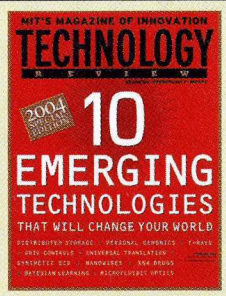

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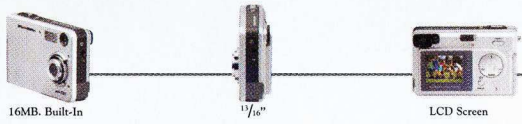

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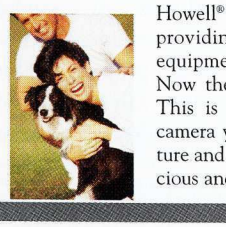

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CBS commentator Walter Cronkite (right) witnesses a demonstration of the Univac by Harold Sweeney and J. Presper Eckert (center).

COURTESY OF UNISYS CORPORATION

Picking the President

More than a half-century ago, the world's first commercial computer made a splash with its right-on-target election night projection. **BY DAN CHO**

"It's awfully early, but I'll go out on a limb," read the printout, just above the prediction that the winner of the 1952 presidential election would be Dwight Eisenhower. Onlookers were skeptical, but with only 1 percent of the vote counted, the Universal Automatic Computer—better known as Univac—had calculated the winner.

The demonstration was a milestone in the pioneering machine's somewhat shaky journey from the laboratory to the real world. The Univac was created by J. Presper Eckert and John W. Mauchly, University of Pennsylvania scientists who in 1946 left academia to form a computer company. Financial woes forced the pair to sell the business to New York-based Remington Rand, though they continued to work from their Philadelphia offices. In 1951, Remington Rand shipped the first Univac to the U.S. Census Bureau. Weighing 13,000 kilograms and boasting more than 5,000 vacuum tubes, the Univac multiplied figures more than 50 times faster than the era's punch-card calculators.

Sales were limited at first to a few government agencies. Then, in 1952, Remington Rand reached an agreement with CBS to have a Univac predict a winner early on election night. The computer worked from the company offices while the station set up a dummy Univac console as a studio prop. At 8:30 P.M. on November 4, the Univac churned out a forecast based on early returns from a few states and past voting patterns. It predicted 438 electoral votes for Eisenhower and 93 for Adlai Stevenson, with odds of 100 to 1 that Eisenhower would win. This result alarmed its creators, for polls had indicated a much closer race. Convinced of an error, the company fiddled with the program to produce odds of a mere 8 to 7 in favor of Eisenhower, which CBS duly reported.

As the night wore on, however, it became clear that the landslide was real. The actual electoral-vote count was 442 to 89 in favor of Eisenhower, amazingly close to the Univac's original prediction. In spite of Remington Rand's initial loss of nerve, the stunt worked. For the next several years, Univac was synonymous to the public with the word "computer."

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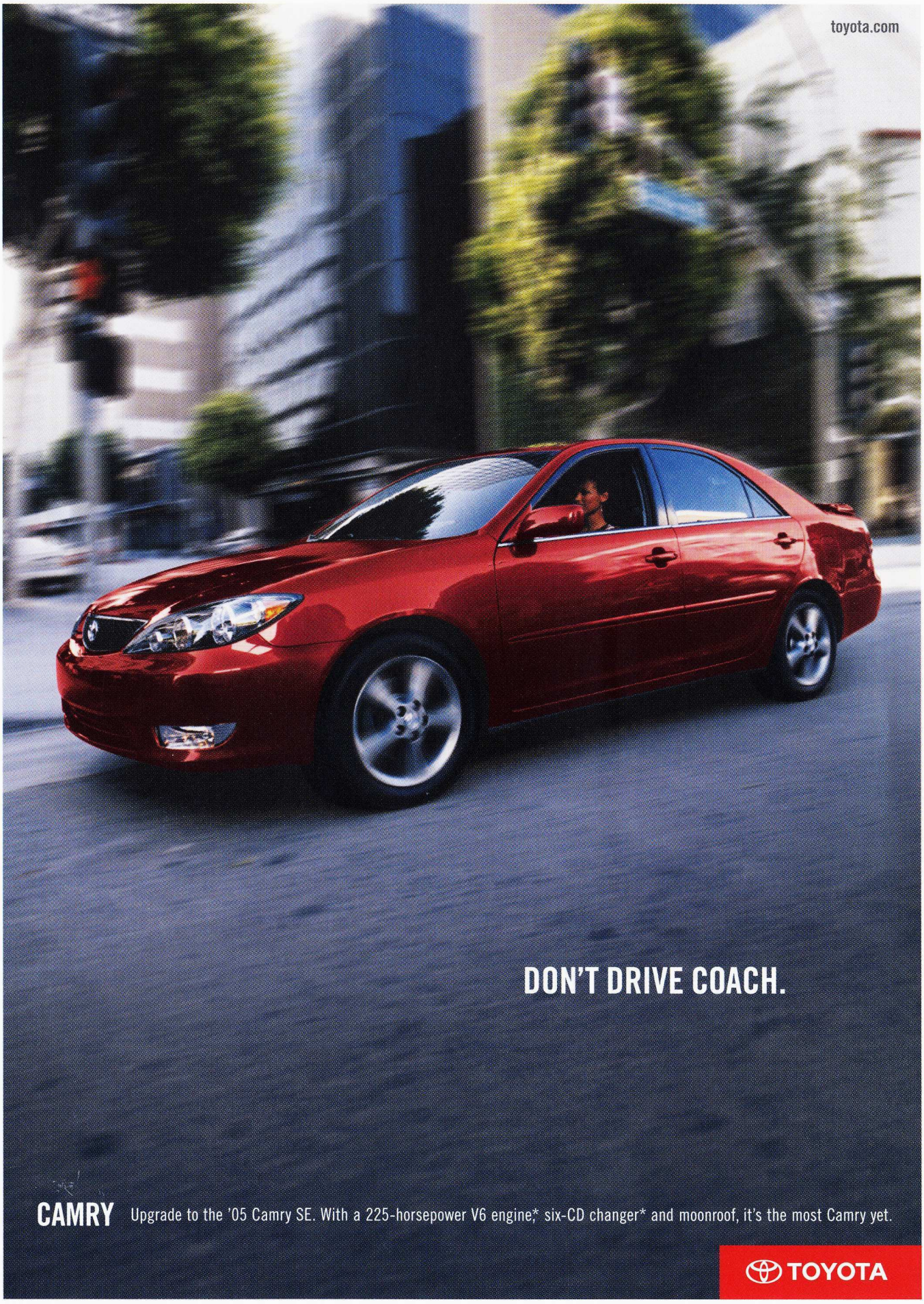

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